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Astronomy®

AMERICA'S BEST-SELLING ASTRONOMY MAGAZINE

August 2002

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See Incredible Photos
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Finding a Livable Neighborhood in the Milky Way

New Telescope Seeks Infant Planets

Binocular Stargazing Tips

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LX200GPS

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Right-to-left: Meade 8", 10", and 12" LX200GPS Schmidt-Cassegrain telescopes. Manufactured under U.S. Patent No. 6,304,376; other patents pending in the U.S.A. and worldwide.

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ADVANCED PRODUCTS DIVISION

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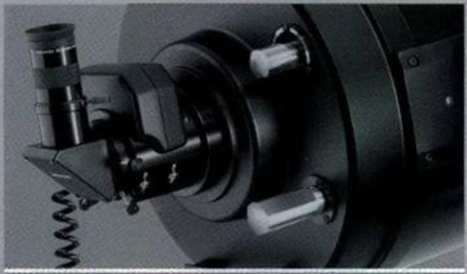
Meade® LX200GPS: the most important advance in Schmidt-Cassegrain technology in ten years is here.

For the visual observer, the astrophotographer, the CCD imager: all the telescope you could possibly have imagined.

For the advanced amateur, new Meade LX200GPS telescopes offer absolutely state-of-the-art optical, mechanical, and electronic performance unmatched by any competing models. Standard-equipment features include:

Precision GPS Alignment: Telescope alignment is accomplished automatically using integrated true-level and North electronic sensors in combination with a 16-channel GPS receiver located in the left-hand fork arm. Magnetic declination compensation is designed into the software and automatically engaged. Just press the *ENTER* button on the Autostar II hand controller and watch as the telescope slews at 8°/second to its first alignment star. *Competing GPS telescopes use a 12-channel receiver (resulting in slower and less reliable position acquisition), do not include any magnetic declination compensation, and can easily result in first-alignment-star errors of up to 20° or more.*



All LX200GPS models include the Zero Image-Shift Microfocuser as standard equipment. The primary mirror lock-knob is located directly above the manual focus knob.

Revolutionary rear-cell systems that enable new levels of precision in focusing in all photo-visual applications and in image centering on CCD chips:

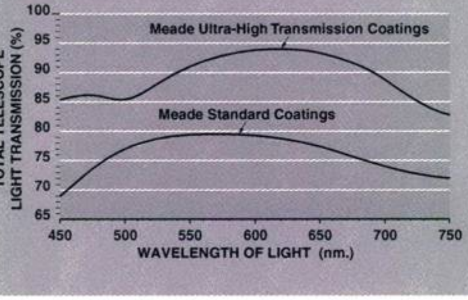
Primary Mirror Lock: Flip a knob located just above the manual coarse-focus knob and lock the telescope's primary mirror rigidly in place. Used with the Zero Image-Shift Microfocuser *(below)* the primary mirror lock cancels any residual image shift while focusing during visual, photographic, or CCD imaging applications.

Zero Image-Shift Microfocuser: Now you can obtain the most precise image focus possible — truly to a microscopic level — during visual and astrophotographic applications, and, during CCD applications, simultaneously maintain precise image centration on even the smallest CCD chips. Included as standard equipment with all LX200GPS Schmidt-Cassegrain models, the Meade Zero Image-Shift Microfocuser operates at 4 different speeds from extremely slow to fast and is actuated through the Autostar II handbox. Coarse manual focusing is effected through the telescope's manual focus knob.

The new Autostar II control system includes all of the features of previous LX200 models and in addition includes an expanded 3.5 Megabyte memory, with a greatly enlarged database of more than 145,000 celestial objects. A partial listing of Autostar II database libraries and numbers of objects:

New General Catalog (NGC)	7840
Index Catalog (IC)	5386
Uppsala Galaxy Catalog	12,940
Morphological Catalog of Galaxies	12,939
General Catalog of Variable Stars	28,484
SAO, Hipparcos, and Draper Star Catalogs	63,404
Large Bright Quasars Survey (LBQS)	1055
Messier (M) and Caldwell Catalogs	219
Herschel Catalog	400
Abell Catalog of Galaxy Clusters	2712
Arp Catalog of Irregular Galaxies	645
Major planets from Mercury to Pluto	8

Meade Ultra-High Transmission Coatings (UHTC) Group: Available optionally at the time of telescope purchase, the UHTC group increases image brightness by 20% over the visible spectrum. See graphs below.



SPECIFICATIONS: 7", 8", 10", and 12" LX200GPS — Each complete telescope includes 8", 10", or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally; see below); primary mirror lock; 4-speed zero image-shift microfocuser; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and 7-port multi-function control panel, including two RS-232 serial interface ports; manual and electric slow-motion controls on both axes; Autostar II control system with 3.5-Megabyte flash memory, digital readout display, permanently programmable Smart Drive and 185-speed drive controls on both axes, High-Precision Pointing, and GO TO controller; 145,000-object onboard celestial software library; GPS alignment system with 16-channel GPS receiver, magnetic declination compensation, and true-level and North electronic sensors; 12vDC telescope power supplied from internal battery compartments accepting 8 (user-supplied) C-cells (optional 25 ft. cords available for powering from auto cigarette lighter plug or from 115vAC); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

MEADE LX200GPS SCHMIDT-CASSEGRAIN TELESCOPES

8" LX200GPS	**$2495**
10" LX200GPS	**2995**
12" LX200GPS	**3995**
7" LX200GPS Maksutov-Cassegrain	**2995**

Ultra-High Transmission Coatings (UHTC) group increases image brightness by 20% *(see ad in June 2002 issue)*: 8" LX200GPS – $175; 10" LX200GPS – $235; 12" LX200GPS – $295; 7" LX200GPS – $150.

Packing & shipping charges in the 48 states: 8" – $105; 10" – $145; 12" – $215; 7" – $125. Prices shown are suggested U.S. national mail-order retail prices.

A COMPARISON OF GPS SCHMIDT-CASSEGRAIN TELESCOPES

	Meade LX200GPS	Competing 11" GPS*
GPS Receiver	16-channel	12-channel
Magnetic declination compensation	yes	no
True-level electronic sensor	yes	no
Primary mirror lock	yes	no
Zero image-shift microfocuser	yes	no
Maximum slew speed	8°/second	3°/second
Drive speeds, each axis	185 speeds, from .01x sidereal to 8°/sec.	9 speeds, from 0.5x sidereal to 3°/sec.
Tracking rates	sidereal, lunar, or custom-selected from 2000 rates	sidereal, lunar, or solar
Memory	3.5-Meg flash	1.0-Meg flash
GO TO pointing precision	2-arcmins	unstated
High-precision pointing mode	yes; permits GO TO pointing precision within 1-arcmin	no
Permanent Periodic Error Correction	yes, both axes	one axis only; second axis unprogrammable
Object database	147,541 objects	"40,000+"
Encoder resolution	0.14 arcsecs	0.26 arcsecs
Internal battery compartments for battery powering	yes; batteries located internal to fork arms	no
RS-232 software download	yes; object libraries and software downloads available	not currently available on factory website
Tracking calibration	not required	recommended after changes in telescope position or load

*Based on sample and instruction manual received in 7/01.

AUTHORIZED MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

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Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.

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Astronomy®

COVER PHOTO: NASA, ESA, H. Ford (JHU), et al., and the ACS Science Team

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The revitalized Hubble Space Telescope and its new Advanced Camera for Surveys return a treasure-trove of wonderful images. *Richard Talcott*

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Although the human eye can't detect the radiation from cool, dusty areas of the cosmos, a powerful new observatory on top of Mauna Kea will. *Angela Swafford*

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We can thank our lucky stars that the sun formed where it did in the Milky Way — life would have had a hard time getting started in most other places. *Mark A. Garlick*

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Telescopes offer a grand view of the sky, but you might be amazed at what two eyes looking through a pair of binoculars can see. *Phil Harrington*

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As the summer Milky Way begins to set in the west, the constellations of autumn arrive with a nice selection of galaxies and star clusters. *Tom Polakis*

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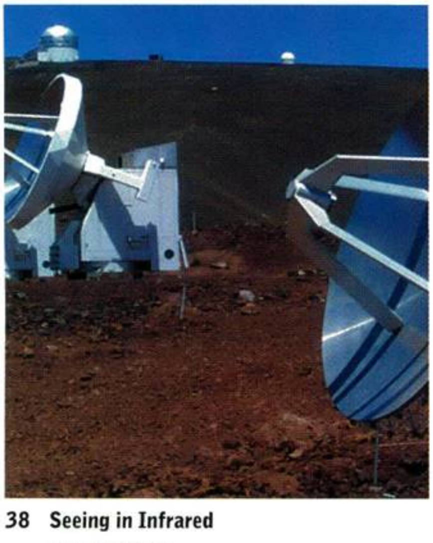

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Harvard University

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68 Capricornus From *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

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BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Catching a Distant Pillar

Processing the image of the amazing scarlet-edged pillar that graces the cover of *Astronomy* began a decade ago at Johns Hopkins University with the design of some powerful new electronic cameras. The project was pushed along further by the efforts of NASA and seven shuttle crew members who went into space for the fourth Hubble Telescope Servicing Mission.

We paid close attention in March when the shuttle servicing team went off toward the Space Telescope. Hubble is 12 years old and aging, even in the eyes of its own designers. The hazards of life in space — radiation, meteoroid and debris impact, temperature extremes — threaten to turn any orbiting spacecraft into space trash. Careful maintenance and several upgrades have offered Hubble unexpected longevity. And now, says John Grunsfeld, payload commander of Servicing Mission 3B, "This mission has turned Hubble into a brand new telescope."

NASA

Astronauts remove Hubble's Faint Object Camera to make room for the new, more powerful Advanced Camera for Surveys.

(Many of these midlife upgrades were planned for Servicing Mission 3 in June 2000. However, gyroscope problems on Hubble forced NASA to bump that launch up to December 1999, before much of the new hardware was ready. It became known as Servicing Mission 3A; and this, the fourth mission, became Servicing Mission 3B.)

Astronauts James Newman and Michael Massimino left the comforts of the shuttle for the outdoors when they walked in space on March 7 to install the phone-booth sized Advanced Camera for Surveys, a camera system that has improved Hubble's vision by more than ten times. Principal investigator and leader of the ACS science team Holland Ford predicts that with this camera, scientists will see the first generation of galaxies.

On April 30, the first photos from Hubble's new camera entered the public domain, courtesy of NASA. See all of Hubble's newly released images and fill in the details of the servicing mission beginning on page 30. Senior editor Rich Talcott writes about the distant, tantalizing images, the mission, and all the Hubble improvements, including repairs on NICMOS — the infrared camera that hasn't functioned since 1999 — and changes in the spacecraft's electrical system.

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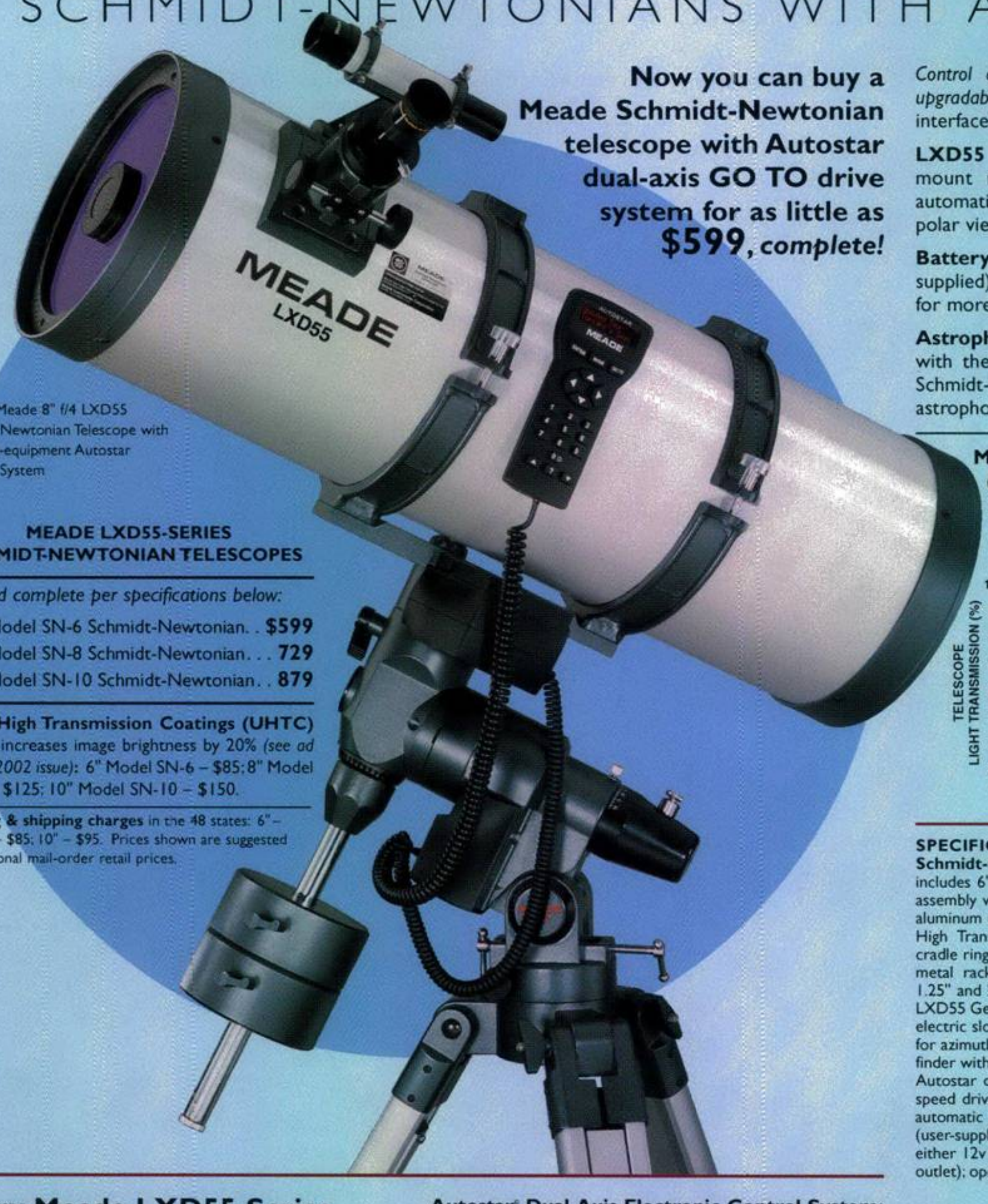
LXD55

6" 8" 10"

SCHMIDT-NEWTONIANS WITH AUTOSTAR®



Now you can buy a Meade Schmidt-Newtonian telescope with Autostar dual-axis GO TO drive system for as little as $599, *complete!*

Shown: Meade 8" f/4 LXD55 Schmidt-Newtonian Telescope with standard-equipment Autostar Control System

MEADE LXD55-SERIES SCHMIDT-NEWTONIAN TELESCOPES

Shipped complete per specifications below:

6" Model SN-6 Schmidt-Newtonian. .	**$599**
8" Model SN-8 Schmidt-Newtonian. . .	**729**
10" Model SN-10 Schmidt-Newtonian. .	**879**

Ultra-High Transmission Coatings (UHTC) group increases image brightness by 20% *(see ad in June 2002 issue)*: 6" Model SN-6 – $85; 8" Model SN-8 – $125; 10" Model SN-10 – $150.

Packing & shipping charges in the 48 states: 6" – $75; 8" – $85; 10" – $95. Prices shown are suggested U.S. national mail-order retail prices.

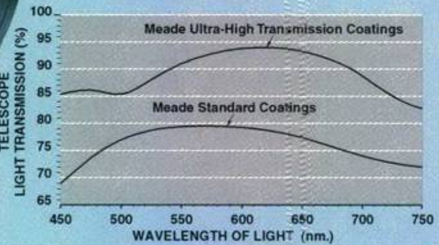
Control of the telescope through your PC and full upgradability over the Internet, using the RS-232 serial interface. (Requires optional #505 Connector Set.)

LXD55 Equatorial Mount: The Meade LXD55 mount moves effortlessly in either tracking or automatic GO TO modes. Included is an illuminated polar viewfinder for fast, precise polar alignment.

Battery Pack (12v DC): Accepts eight (user-supplied) D-cell batteries, which power the telescope for more than 40 hours.

Astrophotography and CCD imaging: Armed with their fast photographic speeds, Meade LXD55 Schmidt-Newtonians are ideally suited for deep-space astrophotography and CCD imaging.

Meade Ultra-High Transmission Coatings (UHTC) Group: Available optionally at the time of telescope purchase, the UHTC group increases image brightness by 20% over the visible spectrum. See graphs below.



SPECIFICATIONS: Models SN-6, SN-8, and SN-10 Schmidt-Newtonian Telescopes — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); quick-release cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12v DC auto cigarette lighter plug or from 115v AC home outlet); operating instructions.

Every Meade LXD55-Series Schmidt-Newtonian telescope includes as standard equipment:

Schmidt-Newtonian optical system: LXD55 diffraction-limited Schmidt-Newtonian optics yield pinpoint stellar images over extremely wide fields, with *one-half* the coma of paraboloids of the same focal ratios. Combined with fast f/4 (8", 10") or f/5 (6") optics, the standard-equipment Super Plössl 26mm eyepiece yields an actual field in excess of 1.3°, for brilliant, rich-field imaging of nebulae, galaxies, and star clusters. The optics are mounted in aluminum cells fitted to white-enameled metal tubes; each tube includes the giant Meade rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces.

Autostar® Dual-Axis Electronic Control System: The exclusive patent-pending Meade Autostar system permits an amazing range of capabilities never before offered on telescopes in this price and aperture class:

Automatic GO TO capability at 4.5°/sec. on both axes to 30,223 objects, including:

13,235 deep-sky objects – galaxies, nebulae, star clusters; 16,888 stars; 50 Solar System objects – the 8 major planets, 26 asteroids, 15 comets, the Moon; 50 Earth satellites; 200 memory locations for user-defined objects.

Automatic GO TO capability to *any* object of known R.A. and Declination.

Nine selectable slew and slow-motion speeds.

Automatic sidereal-rate tracking in R.A. keeps objects precisely centered in the field.

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MEADE®

LXD55 5" 6"

ACHROMATIC REFRACTORS WITH AUTOSTAR®

Complete with LXD55 mounting, diffraction-limited optics, and Autostar controller — as little as $695!

Multi-Coated Achromatic Lenses: With objective lenses that resolve to the theoretical limits for their apertures, Meade 5" and 6" LXD55 refractors present all of the diffraction-limited optical performance obtainable from the classical 2-element achromat design. Lunar, planetary, and deep-space images are rich in resolution and contrast, with a minimum of chromatic aberration.

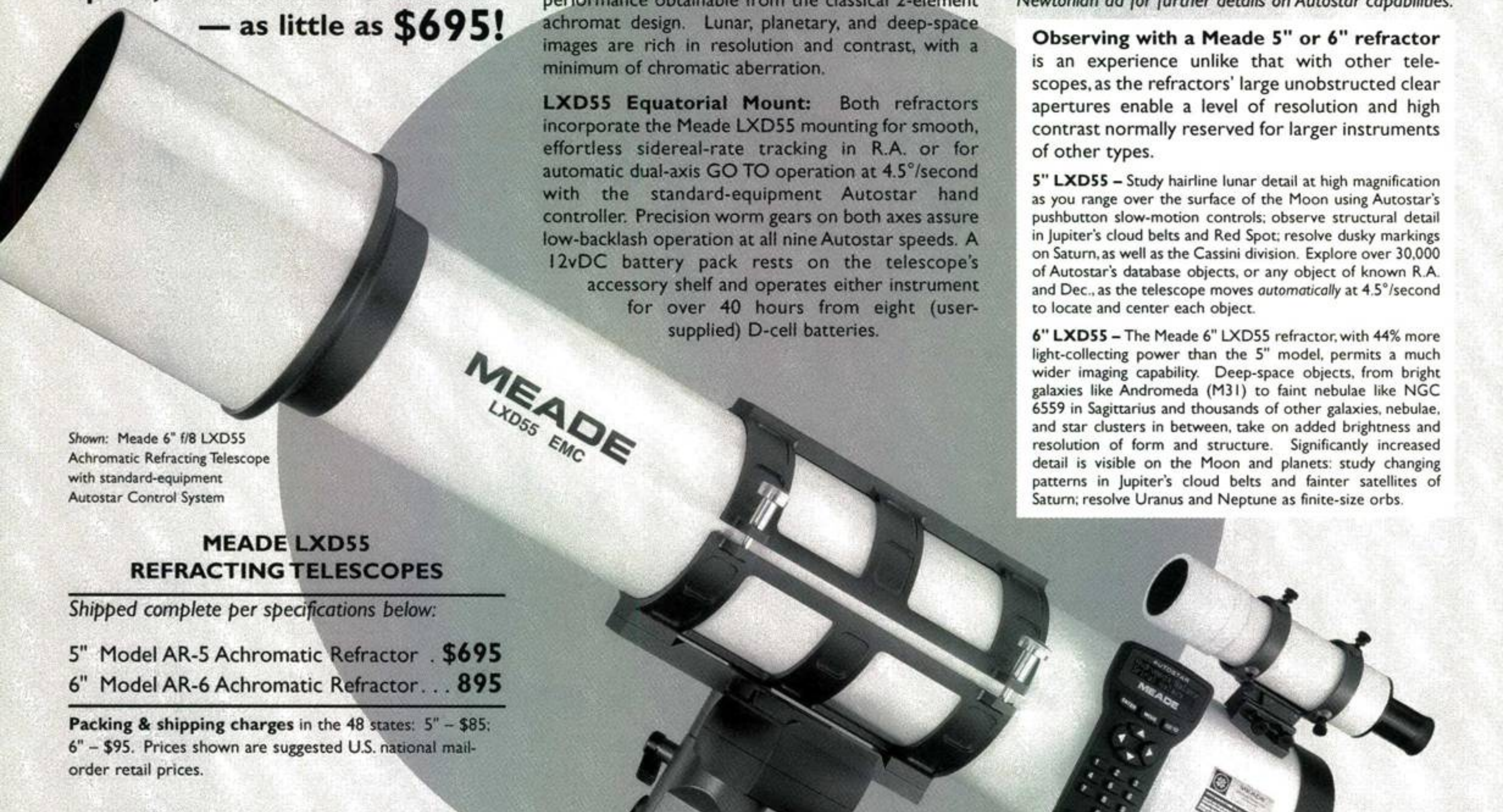
LXD55 Equatorial Mount: Both refractors incorporate the Meade LXD55 mounting for smooth, effortless sidereal-rate tracking in R.A. or for automatic dual-axis GO TO operation at 4.5°/second with the standard-equipment Autostar hand controller. Precision worm gears on both axes assure low-backlash operation at all nine Autostar speeds. A 12vDC battery pack rests on the telescope's accessory shelf and operates either instrument for over 40 hours from eight (user-supplied) D-cell batteries.

Autostar Dual-Axis Electronic Control System: Locate any of 30,223 celestial objects in the Autostar database – automatically – at a push of the GO TO button. *See the Meade LXD55 Schmidt-Newtonian ad for further details on Autostar capabilities.*

Observing with a Meade 5" or 6" refractor is an experience unlike that with other telescopes, as the refractors' large unobstructed clear apertures enable a level of resolution and high contrast normally reserved for larger instruments of other types.

5" LXD55 – Study hairline lunar detail at high magnification as you range over the surface of the Moon using Autostar's pushbutton slow-motion controls; observe structural detail in Jupiter's cloud belts and Red Spot; resolve dusky markings on Saturn, as well as the Cassini division. Explore over 30,000 of Autostar's database objects, or any object of known R.A. and Dec., as the telescope moves *automatically* at 4.5°/second to locate and center each object.

6" LXD55 – The Meade 6" LXD55 refractor, with 44% more light-collecting power than the 5" model, permits a much wider imaging capability. Deep-space objects, from bright galaxies like Andromeda (M31) to faint nebulae like NGC 6559 in Sagittarius and thousands of other galaxies, nebulae, and star clusters in between, take on added brightness and resolution of form and structure. Significantly increased detail is visible on the Moon and planets: study changing patterns in Jupiter's cloud belts and fainter satellites of Saturn; resolve Uranus and Neptune as finite-size orbs.



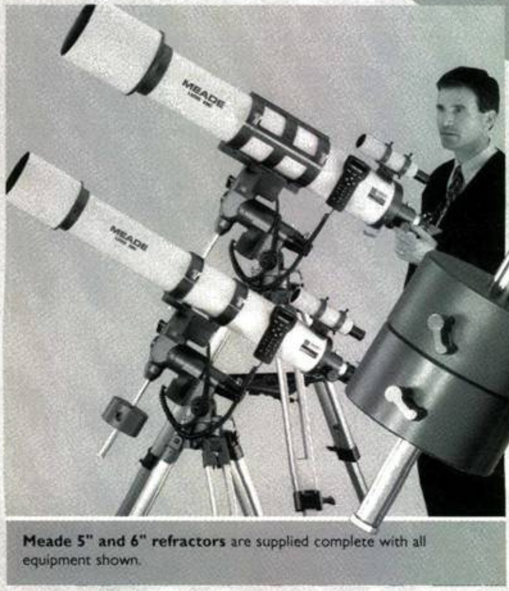
Shown: Meade 6" f/8 LXD55 Achromatic Refracting Telescope with standard-equipment Autostar Control System

MEADE LXD55 REFRACTING TELESCOPES

Shipped complete per specifications below:

5" Model AR-5 Achromatic Refractor .	**$695**
6" Model AR-6 Achromatic Refractor . . .	**895**

Packing & shipping charges in the 48 states: 5" – $85; 6" – $95. Prices shown are suggested U.S. national mail-order retail prices.



Meade 5" and 6" refractors are supplied complete with all equipment shown.

SPECIFICATIONS: 5" and 6" LXD55-Series Achromatic Refractors — Each complete telescope includes 5" f/9 or 6" f/8 achromatic refractor optical tube assembly with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 8 x 50mm achromatic viewfinder; all-metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece; diagonal prism. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.

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Lagoon Nebula
Messier 8
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ENTER
MODE
GO TO
COMPUTER CONTROL
AUX
HBX
ON
OFF
AUX
MEADE

70 • 90 • 105 • 125 ETX MEADE AUTOSTAR

"...A prediction: The ETX/Autostar concept will go down as the greatest happening in amateur astronomy yet."
— *Sky & Telescope*, May, 1999

ETX-105EC, shown with optional #497 Autostar controller and T-Adapter.

Since their inception in 1999, Meade ETX telescopes have gone on to become the largest-selling modern telescopes in the world, with hundreds of thousands of ETX's now in the field. And every one with the unique ETX trademarks: matchless optical performance; compact, contemporary design; and revolutionary Autostar GO TO capability. *See the Meade General Catalog for full details.*

MEADE ETX ASTRO TELESCOPES

Complete per catalog specifications:

ETX-70AT with #494 Autostar	**$349**
ETX-90EC with Electronic Controller	**495**
ETX-105EC with Electronic Controller	**695**
ETX-125EC with Electronic Controller	**895**
#497 Autostar controller for ETX-90EC, ETX-105EC, or ETX-125EC	**149**

Ultra-High Transmission Coatings (UHTC) group increases image brightness by 20% *(see ad in June 2002 issue):*
ETX-90EC– $50; ETX-105EC– $75;
ETX-125EC– $95

Prices shown are suggested U.S. mail-order retail prices.

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MEADE

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each: **$79.95** (4.54)
32mm (52°); **40mm** (44°)	each: **99.95** (5.26)
56mm (52°; 2")	**199.95** (7.02)

Series 4000™
2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

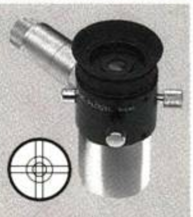
Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™
Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)- **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 3000™ Plössls
50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm (*far right in photo*), an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm $79.95** (3.86)

Series 4000 Photo-Visual Color Filters (1.25")-Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels.

$16.95 (2.73)

Series 4000™
f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (5.26)

#911B
#911N
#908B
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade 60-layer interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces.

$49.95 (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes UHTC-coated (95%+ reflectivity) precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. (Not for LX200GPS models.)

$149.95 (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

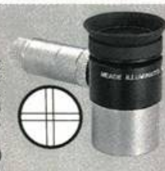
$79.95 (6.85)

Vibration Isolation Pads

Designed by Meade engineers, these isolation pads reduce typical telescope-tripod vibration damping times to *less than* one second. A tremendous aid for both visual and photographic astronomy. Place one pad under each tripod leg. #895 Vibration Isolation Pads, per set of three:

$49.95 (6.85)

MA12mm Illuminated Reticle Eyepiece



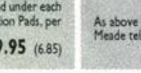
Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

$79.95 (5.26)

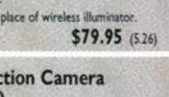
Camera Adapters



Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (3.86)

Variable-Projection Camera Adapter (1.25")



Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with **any** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces.

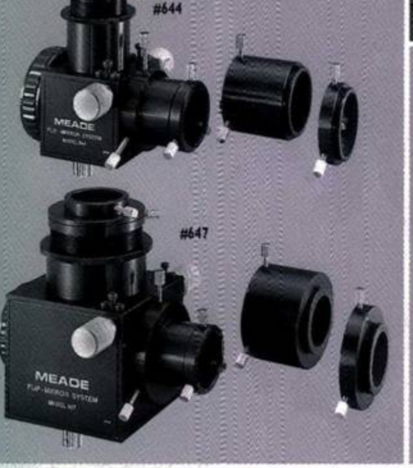
$149.95 (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces.

249.95 (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.)

15.00 (3.86)



#1209 Zero Image-Shift Microfocuser

Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate hand-box for use with all other Meade SCT models (e.g. LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries.

$249.95 (9.85)

Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $99!

Epoch 2000sk *(upper display at left)*: Use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** Dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely! Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software: Enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet.

EPOCH 2000sk Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog, supplied on CD-ROM for Windows 95, 98, 2000, NT, and XP **$99**

LX200 Interface Cable: for Meade LX200/LX200GPS operation by Epoch 2000sk. **25**

EPOCH 2000ip Image Processing Software: On CD-ROM for Windows 95, 98, 2000, NT, and XP . . . **99**

CCD f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2**. Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated: 41mm clear aperture.

$149.95 (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models; ST-4 through ST-8; AP1, AP2; and others. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25".

$129.95 (4.54)

#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing.

$49.95 (4.26)

#64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera.

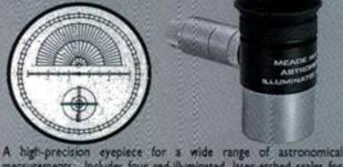
$34.95 (3.86)

#932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics.

$49.95 (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photoguiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25".

$119.95 (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25".

$219.95 (6.38)

ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

#774 Case for ETX-90 models:
99.95 (8.58)

#776 Case for ETX-105EC:
99.95 (8.58)

#775 for ETX-125EC:
149.95 (13.38)

Dew Shields for ETX®

Threads into the front-lens cell and effectively inhibits the formation of dew on the lens surface.

#670 for ETX-60/70	**19.95**
#673 for ETX-90	**24.95**
#675 for ETX-105	**27.95**
#678 for ETX-125	**29.95**

Pictor 216XT CCD Autoguider/Imager

The most advanced Autoguider/Imager in its price class. For many, all the CCD imager required for a wide range of lunar, planetary, or deep-space applications. Includes the same "point-and-shoot" simplicity of larger Pictor models. Produces smooth, natural 16-bit images of all celestial subjects. Also a precision autoguider during astrophotography.

$695. (12.00)

Advanced Field Tripod for ETX-125

#887: Yields rock-solid stability for sensitive applications of the ETX-125, even at high magnifications. **Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125.** Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport.

$349.95 (14.00)

#889 Adapter: Available separately, permits attachment of ETX-125 to any Meade LX10 or LX200 Field Tripod or wedge. **$69.95** (7.70)

ETX® Deluxe Field Tripod

#884: Constructed of strong, lightweight steel; designed specifically for ETX-90, ETX-105, and ETX-125 Astro Telescopes. Tripod height adjusts from 25" to 43", for seated or standing observations. Graduated scale for elevation angle from 20° to 90° permits precise polar alignment of the telescope for astronomical applications. Tripod tilts and locks at 90° for terrestrial applications or for altazimuth use with Autostar. Telescope attaches to tripod in seconds with 2 thumbscrews. **Includes custom-fitted carry bag (shown) with pocket for accessories.**

$199.95 (10.00)

ETX® Carry Bag

Soft-padded Cordura-type carry bag with shoulder strap; permits storage of any 90mm ETX model, plus table tripod legs, eyepieces, other accessories.

$36.95 (5.26)

Electric Focusers for ETX®

ELECTRONIC CONTROLLER
MEADE

Meade-engineered for smooth, rapid focusing with ETX-90, -105, or -125. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus through the telescope's Electronic Controller (EC) or through Autostar.

#1244 Electric Focuser for all ETX-90 and ETX-105 models:

$119.95 (6.85)

#1247 Electric Focuser for ETX-125 models:

$119.95 (6.85)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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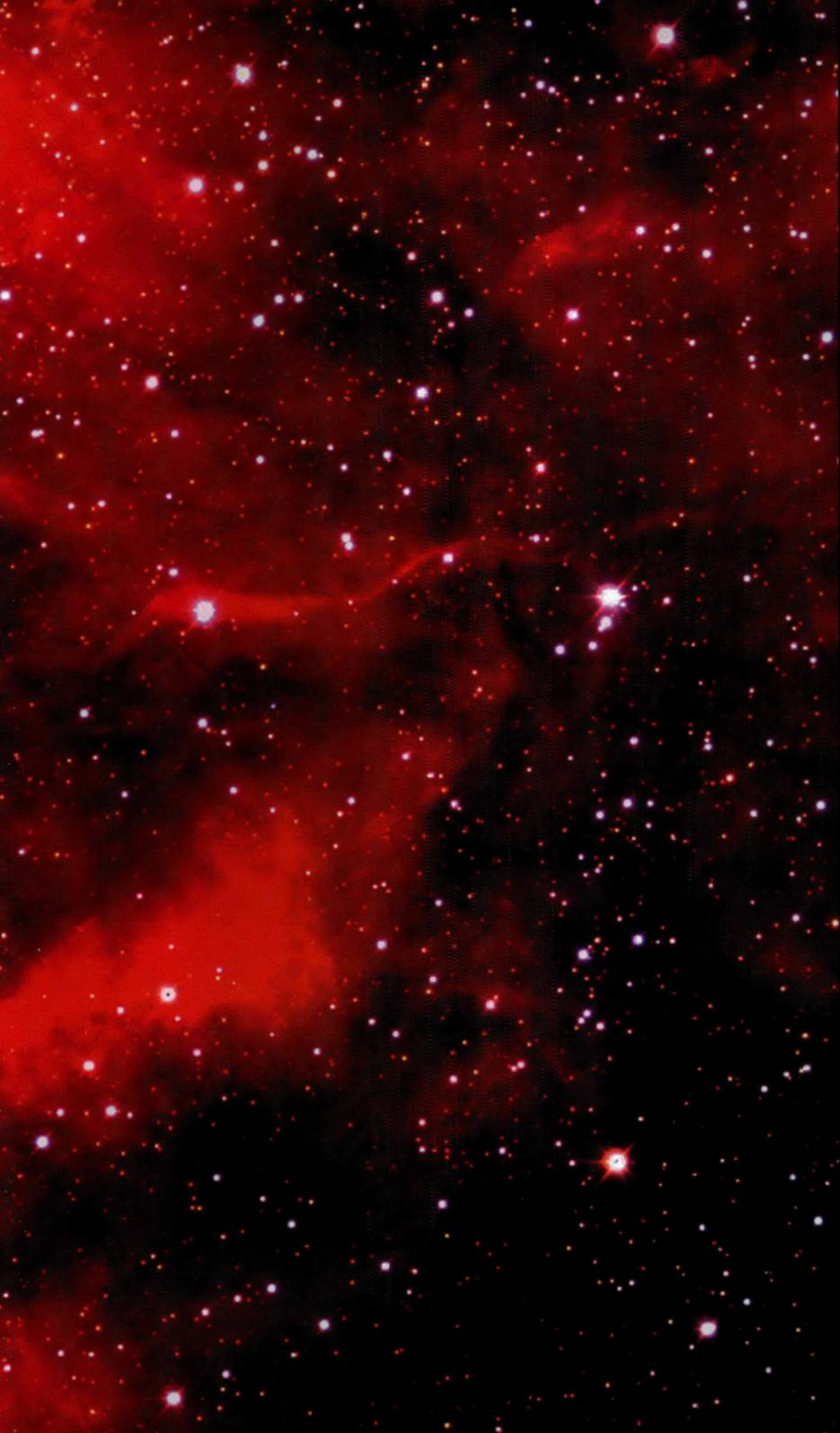

sky Gem

Fiery Heart of the Rosette Nebula

The blazing center of the star cluster NGC 2244 holds some 17 white-hot O and B stars. Intense radiation from these megasuns illuminates the surrounding gas of the Rosette Nebula into luminescence and carves out cavities in the glowing spacescape.

Courtesy J. C. Cuillandre and G. Fahlman, CFHT

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718-437-8810

MEADE ADVANCED PRODUCTS

MAKSUTOV-CASSEGRAINS ETX SCOPES

Exquisite, Diffraction-Limited Imaging in an advanced, ultra portable telescope system!

ETX-90EC Includes:
w/Dual-Axis Drive,
8x21 Erect-Image Viewfinder
& 26mm Plossl

ETX- 125EC Includes:
Dual-Axis Drive,
8x25 Right-Angle Viewfinder
& 26mm Plossl

Optional #497 Autostar controller with GO TO capability **$99**

ETX 60 AT 60mm (2.4"), 350mm f/5.8 w/tripod	$264
ETX 70 AT 70mm (2.8") 350mm f/5 w/tripod	$349
ETX 90EC 1250mm f/13.8	$494
ETX 105EC	$695
ETX 125EC 1900mm f/15	$895
#883 Deluxe ETX Field Tripod (90/105/125)	179
#884 Deluxe ETX Field Tripod (90/105/125) w/carrying bag	199
#64 Photo Adapter f/ETX (90/125)	34.95
#825 8x25 Right-Angle Viewfinder (90)	49.95
#880/#881 Equatorial Table Tripod (90/125)	29.95/59.95
#932 45° Erecting Prism (90/125)	49.95
#1244/#1247 Electric Focuser (90/125)	119.95
#773, #774, #775 Hard Case for ETX	CALL
#772 Carry bag for #883 Delux Field Tripod	CALL
#776 Hard Case for ETX-105EC	CALL

PICTOR CCD IMAGERS 416-XTE & 1616-XTE

With New Kodak Blue-sensitive CCD Chip

For the beginner, or for the most advanced observer, the real CCD revolution is here!

201-XT Autoguider/Imager	395
208-XT Autoguider/Imager	495
216-XT Autoguider/Imager	695
416-XTE Autoguider/Imager	1,995
1616-XTE Autoguider/Imager	6,495
Off Axis Guider f/CCD	89.95
616 Color Filter System f/416, 1616-XT	695
616A Color Filter System f/216	695
520 Electronic Relay f/201, 208, 216, 416, 1616	94.95
541 AC Adapter f/201, 208, 216	36.95
542 AC Adapter f/416, 1616	94.95

EYEPIECES

MODIFIED APOCHROMATIC

9, 12, 25, 40mm 1.25"	37.95	9, 12, 25, 40mm .96"	29.95

PLOSSL SERIES 3000

5, 6.7, 9.5, 16, 25mm 1.25"	49.95	40mm 1.25"	79.95

SUPER PLOSSL SERIES 4000

6.4, 9.7, 12.4, 15, 20, 26mm 1.25"			79.95
32, 40mm 1.25"	99.95	56mm 2"	199.95

PLOSSL SERIES 4000 SUPER WIDE ANGLE

13.8mm 1.25"	139.95	18mm 1.25"	149.95
24.5mm 1.25"	179.95	40mm 2"	299.95
32mm 2"			239.95

PLOSSL SERIES 4000 ULTRA WIDE ANGLE

4.7mm 1.25"	169.95	8.8mm 1.25"/2"	239.95
6.7mm 1.25"	199.95	14mm 1.25"/2"	299.95

ILLUMINATED RETICLE EYEPIECE SYSTEMS

	Wireless	w/Cord
Plossl 9mm 1.25"	149.95	129.95
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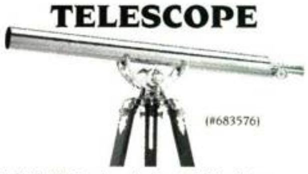

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Naked-Eye Delights

I enjoy reading the many examples in *Astronomy* of the observing experiences one can achieve with the aid of a telescope. However, seeing any objects with the naked eye is a source of excitement for me. As a recent college graduate, my budget does not allow for the luxury of a telescope, and I also live in a highly light-polluted area. But this does not stop me from doing whatever naked-eye observing I can from my backyard. This past autumn, I had the unexpected thrill of seeing Orion's sword. Those three, fuzzy points of light had never before been visible in the city (and I have not seen them since), but that night I spotted them shining dimly. I stared at them in awe, as they were an unexpected treasure. It made my day simply to know that I had spotted the area of sky where M42 resides, even though I couldn't see the nebula itself.

In fact, 2001 turned out to be a year full of backyard celestial wonders. The Big Dipper is always visible in the city, although I have never seen the rest of Ursa Major. I was delighted to discover that Cepheus does indeed look like a house. Long ago I learned to spot the "teapot" of Sagittarius, and last August I was proud to learn I had correctly identified Cygnus the Swan. The planets also provide a particular challenge for me, but in June 2001 I enjoyed seeing the dim red glow of Mars even without the aid of a telescope.

In the future, I hope to be able to gaze at the sky through a telescope under dark skies. But until then, I will continue to take in as much as I can with the naked eye from my backyard in the city. — *Melina Noussias, Canton, Ohio*

A 10-Dimensional Universe?

I have been an *Astronomy* subscriber for more years than I can remember, and I always enjoy the articles. Reading "When Branes Collide" (May 2002) brought back some fond memories. The article mentioned that physicists now think our universe may be composed of 10 dimensions. Maybe this is a coincidence, but in the spring of 1969 my friend Ricky Donnald and I were working as senior-student assistants at our high school in the chemistry lab during our "free" period. With no one else in the lab we began to hypothesize about the number and dimensions of space-time (our physics instructor had recently mentioned four-dimensional space-time, and I had read a little about the Theory of Relativity). Oddly enough we "guessed" that there were 10 dimensions. It was probably blind luck, but I got a kick out of the article. —*Tim Brown, Honea Path, South Carolina*

Jupiter and Saturn, visible without the aid of a telescope, shine in a star-studded sky over the Anza-Borrego Desert. Jerry Schad

Your article, "When Branes Collide" provided some very interesting and intriguing insights into how our universe/multiverse may be structured. It has caused me to rethink some of my own personal cosmological theories. I would, however, like to suggest that perhaps time can exist in multiple dimensions. We humans perceive time in only one dimension, so it may stand to reason that we cannot comprehend how time could flow otherwise. Consider an imaginary being existing on a one-dimensional physical plane. Such a creature probably would not understand a dimension beyond its own, and thus might not try to conjecture any. Perhaps, in our case, the same holds true for time. If time does indeed exist beyond our own perception, it could present interesting solutions to some of the biggest puzzles of the universe. But it could also present some new, even more challenging mysteries. — *Ryan Adornetto, San Bernardino, California*

The Next Great Lineup

On page 74 of the May issue, the author states, "May offers up great viewing for five naked-eye planets (Mercury, Venus, Mars, Jupiter, and Saturn) during the first half of the month. Make sure to catch it while you can, because once this amazing alignment disappears, it's gone until 2020." But on page 90 of the same issue, Bob Berman refers to the alignment, then states that "nothing like it will again be seen until autumn 2040." Which statement is correct? — *Bert Condie, III, St. Louis, Missouri*

Jupiter and Saturn appear near each other in the night sky about once every 20 years (give or take a couple of years.) In the year 2020, these two giant planets will again reside in the same portion of the sky, and Venus will also be visible. But not until 2040 will all five planets – Mercury, Venus, Mars, Jupiter, and Saturn – again light up the sky simultaneously. — Astronomy *editors*

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COSMOLOGY

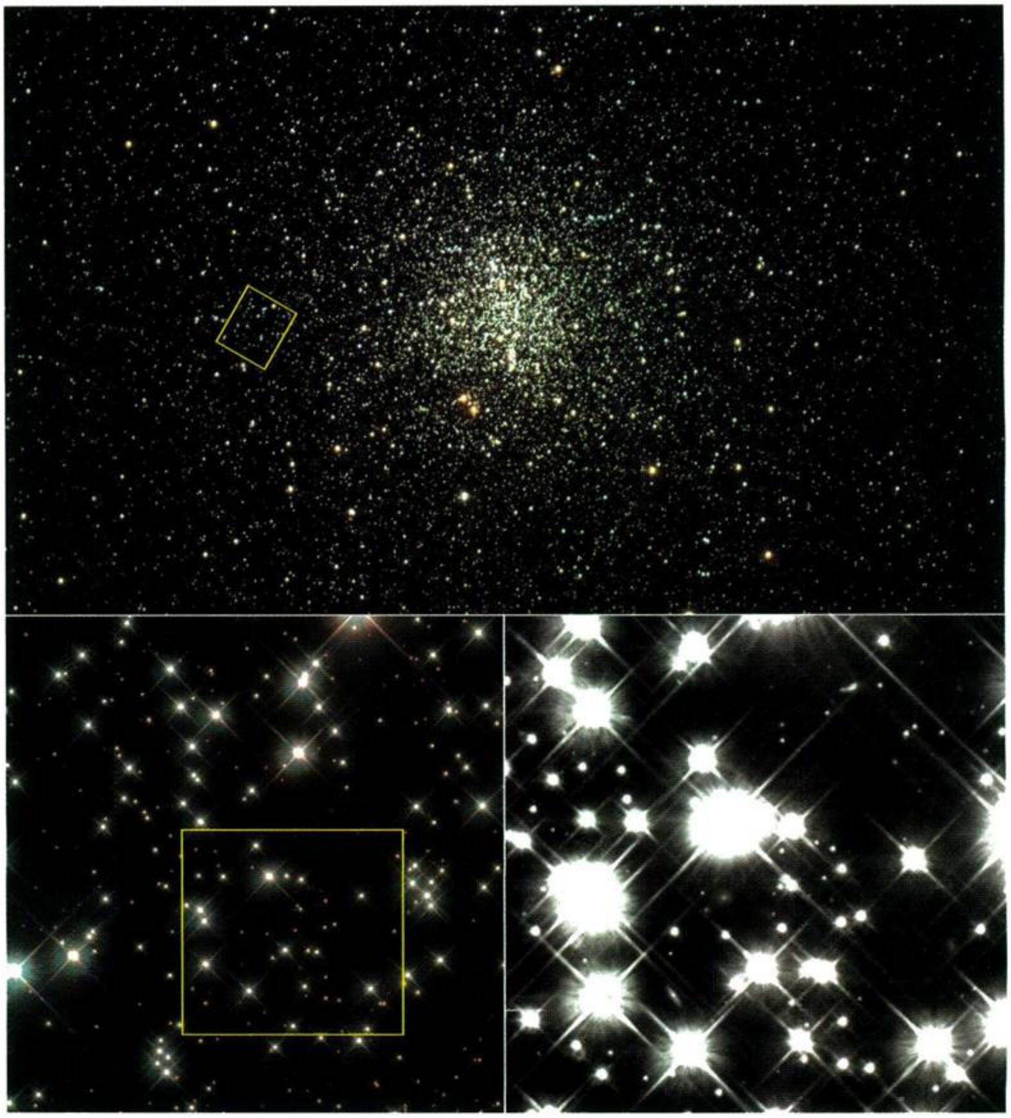
White Dwarfs Pin Down Cosmic Age

▶ When NASA launched the Hubble Space Telescope into orbit onboard the space shuttle Discovery 12 years ago, astronomers set as one of its fundamental goals the task of measuring the age of the universe.

Mission accomplished: A team of scientists led by Harvey Richer of the University of British Columbia has used Hubble to confirm that the cosmos was born between 13 billion and 14 billion years ago. Previous Hubble observations of distant galaxies had already suggested that the universe began with a Big Bang approximately this long ago. But this new confirmation comes from a simple method that uses the dimmest cinders of stars in our own cosmic backyard.

During a 10-week period in early 2001, Richer and his colleagues racked up nearly 8 days' worth of exposure time targeting white dwarf stars in the globular cluster M4 in Scorpius. Astronomers believe that globular clusters were among the earliest structures to form in the universe and existed even before the Milky Way had fully taken shape.

White dwarfs are the senior citizens of these ancient stellar populations. They are the collapsed, Earth-sized remains of moderately sized stars (with masses up to eight times that of the sun) that have exhausted their nuclear fuel. As white dwarfs age, they cool at well-known rates, so astronomers can easily estimate how old they are.



The edge of globular cluster M4 (top) holds white dwarfs (the faintest dots above) that show the universe began 13 billion to 14 billion years ago. Top: NOAO/AURA/NSF; bottom: NASA and H. Richer (UBC)

At a distance of approximately 7,000 light-years, M4 lies closer to Earth than any other globular cluster. That, combined with the extremely long exposure time on Hubble's Wide Field and Planetary Camera 2, allowed Richer's team to pick out the faintest, coolest, and therefore oldest white dwarfs in M4. "The exposure was long enough that if fainter white dwarfs were there, we would've seen them," says Richer.

From the known cooling rates, Richer's team determined that M4's faintest white dwarfs were born just under 13 billion years ago. But the first stars and globular clusters didn't form immediately; according to recent Hubble results, the universe started creating stars within a billion years after the Big Bang. Together, these discoveries date the universe's birth to between 13 billion and 14 billion years ago.

Astronomers view the new method of determining the universe's age as a clean and elegant one because it doesn't require factoring in the expansion rate of the universe, as previous techniques did. According to Bruce Margon of the Space Telescope Science Institute, such traditional methods have "all sorts of complications and involve a lot of assumptions." For example, Wendy Freedman of the Carnegie Observatories previously led a team of astronomers who used Hubble to determine the age of the universe by measuring the distances to Cepheid variable stars and supernovae, taking into account how fast the universe expanded at different times in the past.

The good news is that the age estimates from both methods agree. "The fact that they're in the same ballpark is an important result," says Freedman.

Richer and his colleagues look forward to using the Advanced Camera for Surveys, recently installed on Hubble, to study the oldest white dwarfs in another globular and convince themselves that the age of the universe they derived is correct. — Vanessa Thomas

COSMIC RAYS

Faster than a Speeding Bullet

▶ About once per second, a subatomic particle from space slams into Earth's atmosphere with the energy of a Randy Johnson fastball. Think about that: a subatomic particle (probably a proton) packing the punch of a 100 mph baseball.

The elliptical galaxy NGC 5322 in Ursa Major appears to be one source of ultra-high energy cosmic rays. NASA/HST/Timothy Hamilton

Such is the nature of ultra-high energy cosmic rays, which in physics parlance have the energy of at least 10^{19} electron volts. That's millions of times more energetic than the normal cosmic rays that continually bombard Earth's atmosphere. The origin of these cosmic bullets is one of the great unsolved mysteries in astrophysics. But now, a team of four astronomers has identified a possible source.

At the April meeting of the American Astronomical Society's High Energy Astrophysics Division in Albuquerque, New Mexico, Diego Torres of Princeton University and Elihu Boldt, Timothy Hamilton, and Michael Loewenstein of NASA's Goddard Space Flight Center reported finding a correlation between ultra-high energy cosmic-ray events and four giant elliptical galaxies: NGC 3610, NGC 3613, and NGC 5322 in Ursa Major and NGC 4589 in Draco.

Torres's team analyzed 38 ultra-high energy cosmic-ray events detected by the AGASA array in Japan, the world's largest cosmic-ray detector, and three other events seen by the Haverah Park detector in England. The team compared the arrival direction of these cosmic rays to 12 elliptical galaxies in the same general patch of the northern sky. "We found that four of the galaxies are remarkably well matched to ultra-high energy cosmic-ray arrival directions," says Boldt.

The four elliptical galaxies all harbor supermassive black holes in their cores, but these cores are relatively quiescent. If the cores were active, like quasars, the sheer amount of ambient light around the central black hole would prevent the cosmic-ray particles from being accelerated to such high energies.

The connection between such dormant quasars and ultra-high energy cosmic rays makes theoretical sense. A spinning supermassive black hole combined with powerful magnetic fields creates a dynamo effect that could be capable of accelerating protons to within a whisker of the speed of light, the velocity needed to exceed 10^{19} electron volts in energy.

"This result has a less than 1 percent chance of being a statistical fluke," says Boldt. But other astronomers are taking a wait-and-see attitude. "The model makes a lot of sense and it is plausible, but it needs more experimental evidence," says Michael Cherry of Louisiana State University in Baton Rouge.

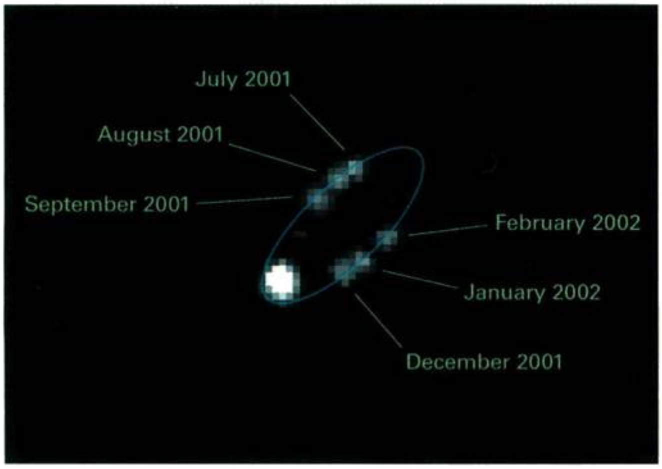
Fortunately, help is on the way. An international consortium is building the Pierre Auger Observatory in Argentina, which will have detectors covering an area the size of Rhode Island. Auger should register more events, which in turn could provide the clues to unlock the great cosmic-ray mystery. — Robert Naeye

KUIPER BELT

Seeing Double at the Cold Edge

▶ Ten years ago, they were but a glimmer in the eyes of theorists. Then in August 1992, theory turned into reality when David Jewitt and Jane Luu sighted the first object orbiting the sun beyond Pluto. In the decade since, several hundred more of these enigmatic objects have been found in the so-called Kuiper Belt — though few concrete details have emerged.

That may soon change. A year ago, Christian Veillet of the Canada-France-Hawaii Telescope Corporation and his colleagues discovered that one of these objects has a binary companion. The researchers have since observed the pair (named 1998 WW31 when it was



Hubble reveals the highly elongated orbit of this binary Kuiper Belt Object. NASA and C. Veillet (CFHT)

sighted as a single dot of light in 1998) with the 3.6-meter Canada-France-Hawaii Telescope and the Hubble Space Telescope, teasing out clues to its nature.

The team reported their findings in the April 18 issue of *Nature*. The two objects orbit around a common center of gravity once every 570 days. But their distance from each other varies by a factor of ten during the orbit, making this the most eccentric orbit ever seen for a binary pair in the solar system. The distance grows from 2,500 miles (4,000 km) at closest approach to 25,000 miles (40,000 km) at greatest separation.

The researchers then used the orbit to calculate the total mass of the pair. They found that the two objects weigh just 0.02 percent as much as the Pluto-Charon system. Making some reasonable assumptions about the objects' density and the amount of light they reflect, the team calculates that the larger object has a diameter between 75 and 90 miles (120 to 150 km). This object measures some 20 percent larger and possesses 75 percent more mass than the smaller component.

It appears that 1998 WW31 may be just the tip of the iceberg. In the year since its binary nature was shown, astronomers have discovered six more binary pairs in the Kuiper Belt. "It's amazing that something that seems so hard to do and takes many years to accomplish can then trigger an avalanche of discoveries," says Veillet. Four of the objects were discovered with Hubble, one with the Canada-France-Hawaii Telescope, and one with the 6.5-meter Baade Telescope at Las Campanas in Chile.

The Kuiper Belt is a vast reservoir of icy bodies that stretches from the orbit of Neptune at 30 astronomical units (AU) to more than 100 AU. (One AU is the average distance of Earth from the sun, about 93 million miles.) Astronomers think these objects are debris left over from the formation of the solar system that were kicked out through gravitational interactions with the giant planets. The discovery and analysis of more binary Kuiper Belt Objects will go a long way toward confirming or refuting this idea. — Richard Talcott

MILLISECOND PULSARS

Giving Birth to a Superfast Pulsar

▶ Of all the strange animals in the cosmic bestiary, few are as wild as the pulsar. Born in the fiery cataclysm of a supernova, a pulsar (or neutron star) contains a couple times the mass of the sun crushed into a sphere the size of a modest city. And to top things off, a newly born pulsar spins at an incredible rate, completing dozens of rotations every second.

If pulsars appear strange, they pale in comparison to an exotic subspecies known as millisecond pulsars. They possess all the odd characteristics of normal pulsars but spin even faster — rotating hundreds of times each second. How they reach this state remains somewhat of a mystery, but a team of astronomers now believes it has found a millisecond pulsar being born.

Most astronomers think millisecond pulsars form when an old pulsar gets

HUBBLE SPACE TELESCOPE

NASA and the Hubble Heritage Team (STScI/AURA)

FILAMENTS OF GLOWING GAS STREAM from a group of hot young stars in the Large Magellanic Cloud. Designated N44C, this region of glowing hydrogen forms just a part of the larger N44 complex. The extreme temperature of the star that illuminates N44C makes it peculiar. The most massive stars, which have masses up to about 50 times that of the sun, reach a maximum temperature of roughly 90,000° F (50,000 kelvins). But the star illuminating N44C appears far hotter, with a temperature that approaches 135,000° F (75,000 kelvins). Astronomers speculate that the star could be a neutron star or black hole that produces x rays intermittently but is currently quiescent. The network of filaments visible in the upper right of this Hubble image surrounds a Wolf-Rayet star. These stars produce a strong stellar wind of charged particles. The shock created when the wind collides with the surrounding gas causes the gas to glow.

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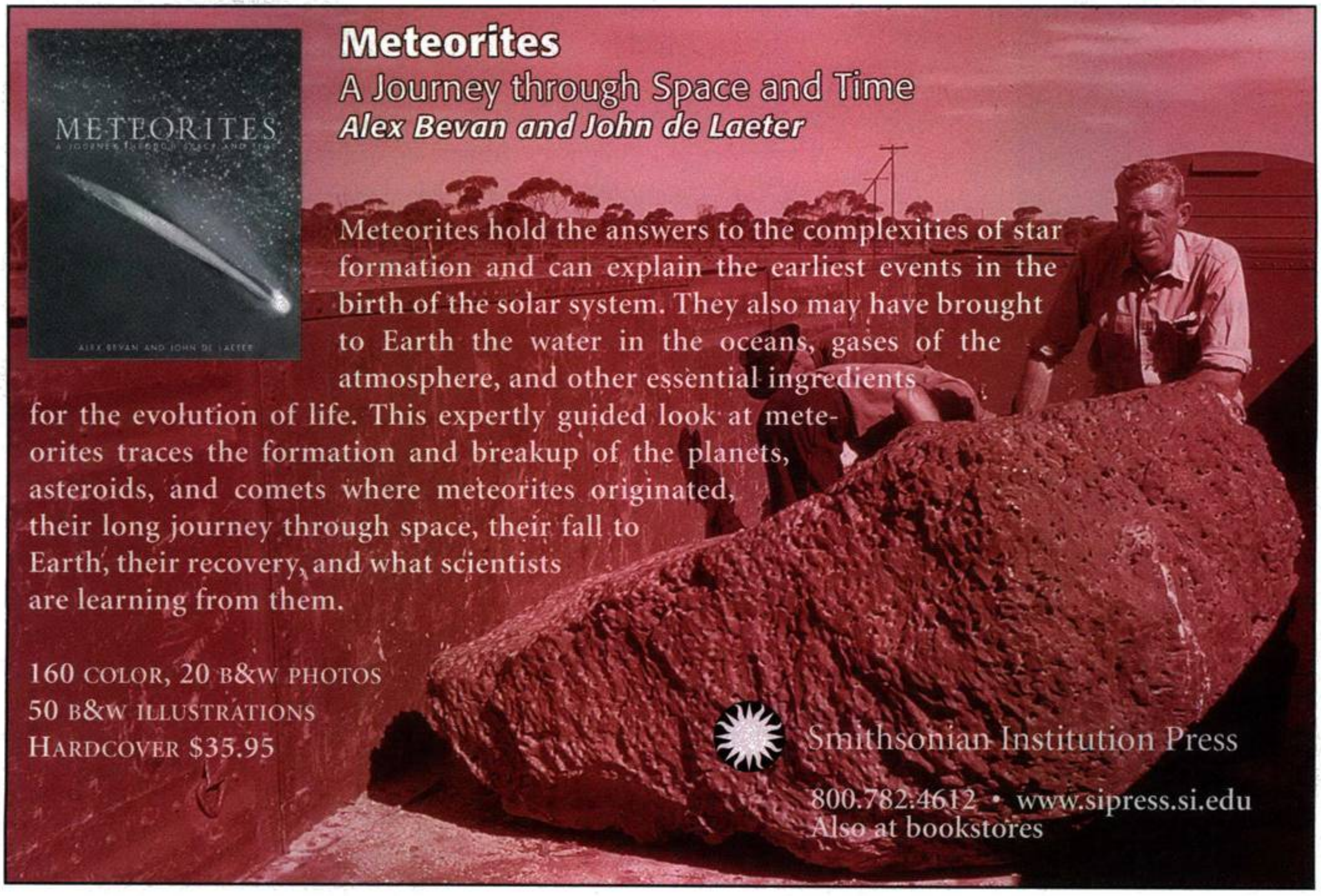

Meteorites
A Journey through Space and Time
Alex Bevan and John de Laeter

Meteorites hold the answers to the complexities of star formation and can explain the earliest events in the birth of the solar system. They also may have brought to Earth the water in the oceans, gases of the atmosphere, and other essential ingredients for the evolution of life. This expertly guided look at meteorites traces the formation and breakup of the planets, asteroids, and comets where meteorites originated, their long journey through space, their fall to Earth, their recovery, and what scientists are learning from them.

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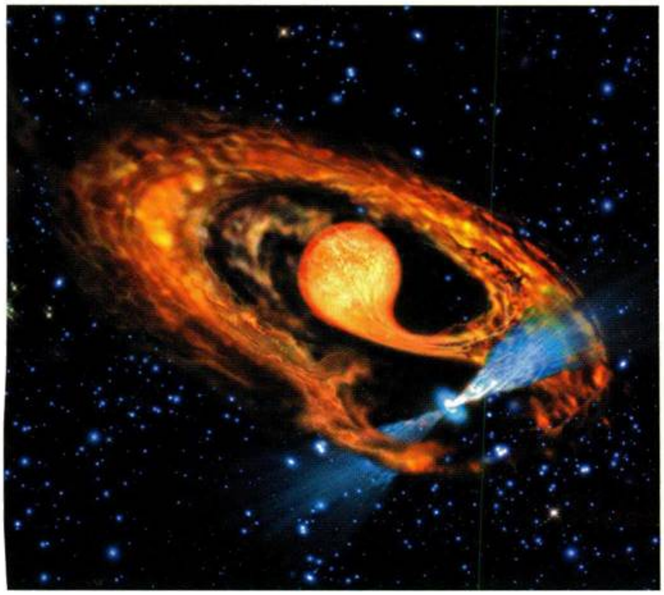
A JOURNEY THROUGH SPACE AND TIME
ALEX BEVAN AND JOHN DE LAETER

"spun up." This scenario starts with an old, slowly rotating neutron star in a binary system. When the neutron star's companion nears the end of its life, it grows into a bloated red giant. The strong gravity of the neutron star pulls matter from the companion, transferring energy to the neutron star and causing it to spin faster. The process continues until the companion evolves into a white dwarf, cutting off the inflow of matter, and the renewed pulsar is spinning hundreds of times a second.

Francesco Ferraro and his colleagues at the Bologna Observatory in Italy targeted a millisecond pulsar in the globular cluster NGC 6397 in Ara. Using both the Hubble Space Telescope and the Parkes radio telescope in Australia, the researchers found the pulsar's companion to be a red giant and not the expected white dwarf. The two orbit each other once every 1.35 days.

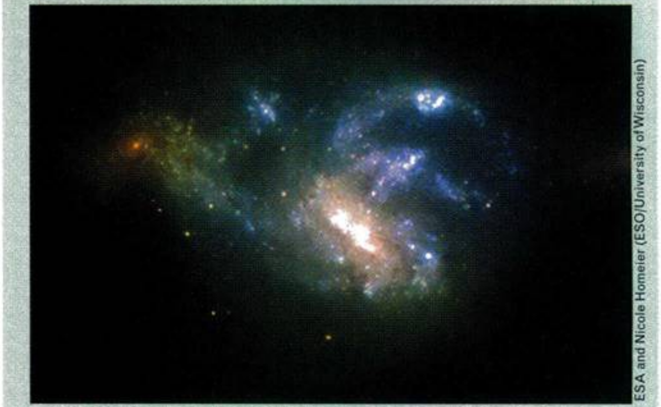
The observations also show a large amount of gas in the system — just what would be expected if material was being transferred between the two stars. "We have certainly discovered a very unusual pair," says Ferraro. "Our favored theory is that we are seeing the system before the bloated red star has been emptied of gas and turned into a white dwarf."

Of course, one example does not prove a theory. Stars in the crowded confines of a globular cluster occasionally switch partners, and the companion could be a red giant that the pulsar captured by chance. Still, the observations offer the best evidence yet on how millisecond pulsars evolve. — R. T.



A newborn millisecond pulsar (left, arrow) appears to be spun up as gas flows onto it from a red giant (below). ESA and F. Ferraro (BAO)

HUBBLE SPACE TELESCOPE



ESA and Nicole Homeier (ESO/University of Wisconsin)

MILLIONS OF NEW STARS BLAZE along the arms of the spiral galaxy NGC 7673. Each of the bluish areas consists of immense star clusters containing thousands of hot young stars. And each cluster radiates 100 times as much ultraviolet light as the Tarantula Nebula in the Large Magellanic Cloud, the largest star-forming region in the Local Group of galaxies. What triggered this intense burst of star formation? Astronomers suspect either a collision with an as-yet-undiscovered galaxy or some internal process, perhaps excess gas in the galaxy's disk that became gravitationally unstable. NGC 7673 lies about 150 million light-years from Earth in Pegasus. The two other galaxies seen in this Hubble image — one to the left of NGC 7673 and one to the right — lie in the background. They appear redder because they are farther away and the expansion of the universe has shifted their light to longer, redder wavelengths.

INTERSTELLAR MEDIUM

Diamonds in the Rough

▶ A few astronomers have found some gems, literally, floating in the space between the stars. In fact, according to new research results reported in the June 10 issue of the *Astrophysical Journal Letters*, diamonds dance among dust clouds that drift in deep space.

Using the Space Telescope Imaging Spectrograph on Hubble and archival data from the International Ultraviolet Explorer satellite, a research team led by astronomer Geoffrey Clayton of Louisiana State University in Baton Rouge detected a carbon crystalline substance in dust clouds enshrouding newborn stars. The researchers suspected that the mystery substance might be diamond, so they compared the ultraviolet signature of their sample to that of diamonds found more than a decade ago in the belly of some meteorites. The spectral data between the two samples was such a tight match that Clayton and his colleagues are confident that they have locked on to interstellar diamonds.

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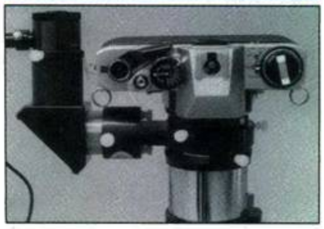

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This vial contains quadrillions of microscopic diamonds extracted from the Murchison meteorite.

University of Chicago

Jewelers shouldn't get too excited, however. These interstellar diamonds probably would not sparkle to the naked eye. After all, they're only a few nanometers across — about a billionth of an inch.

Astronomers believe these diamond grains, like so many other complex molecules in space, were produced in the searing heat and extreme pressure of ancient supernova explosions. Some space rocks must have swept up the diamond dust as our solar system was forming approximately 4.6 billion years ago, explaining the diamonds found in meteorites in the 1980s. Additional observations show that diamonds exist in deep, dark space, not just in the relatively exciting environments of stellar nurseries.

Because supernovae have been pumping out diamonds over the entire history of the galaxy, Clayton and his team reason that they must be a common constituent of interstellar dust. They might possibly account for five percent of the carbonaceous molecules lurking in interstellar space.

Based on this discovery, Clayton estimates that the Milky Way may contain many trillions of tons of diamonds. — Paul Morledge

SOLAR PHYSICS

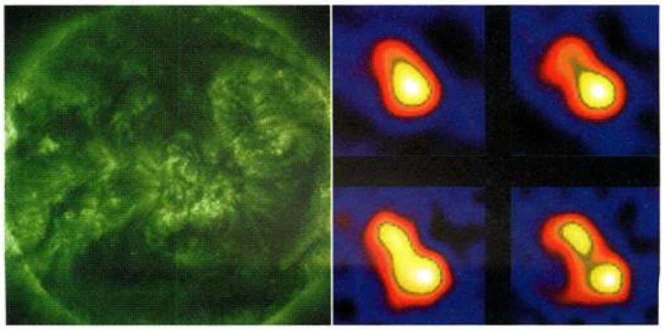
New Probe of the Sun

▶ The sun provides all the light and heat needed to nurture life on Earth. It also produces violent solar flares, which can disrupt communications, satellites, and even power systems. Flares rank among the most enigmatic solar events. Astronomers believe that a violent release of magnetic energy powers them, but how this happens remains a deep mystery. That's why solar scientists seek every bit of information they can get their hands on.

Enter NASA's newest spacecraft. The Reuven Ramaty High-Energy Solar Spectroscopic Imager, or RHESSI for short, began its planned two-year mission to study solar flares on the afternoon of February 5. (Ramaty, who died in 2001, was a pioneer in the fields of solar-flare physics, gamma-ray astronomy, and cosmic rays.)

The spacecraft was tucked inside a Pegasus XL rocket, which was in turn attached to the underbelly of an L-1011 aircraft. The plane carried the rocket to 39,000 feet, and the rocket then delivered the spacecraft into a circular orbit 373 miles above Earth.

RHESSI became fully operational about six weeks after launch, once its detectors had been cooled to their operating temperature of –320° F and thoroughly checked out. It has since been returning the first high-fidelity color movies of solar flares in both x rays and gamma rays.

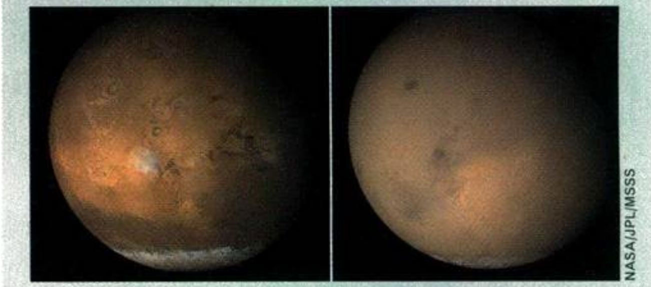


SOHO first saw the solar flare of February 20 (left, below center). RHESSI then captured the flare's x-ray output (right). NASA

"We want to understand how solar flares can explosively release so much energy," says mission scientist Brian Dennis of NASA's Goddard Space Flight Center. "RHESSI shows us the high-energy radiation emitted by flares. This radiation reveals the core of the flare — the exact time and place where the energy is released."

Solar scientists got an unexpected bonus during the spacecraft's commissioning phase. On February 20, a solar flare released the energy equivalent of one million megatons of TNT — a moderately powerful flare by the sun's standards. The flare erupted in the sun's southern hemisphere, from active region 9830. Scientists expect RHESSI to observe hundreds more during the next two years. — R. T.

MARS GLOBAL SURVEYOR



NASA/JPL/MSSS

DUST STORMS RAGED ACROSS MARS during mid-2001, obscuring much of the planet from view. On June 10 (left), most of the surface remained visible. The mighty volcanoes of the Tharsis bulge (at left), the Valles Marineris chasms (right), and the south polar cap (bottom) all show up nicely. By July 31 (right), as winter was ending and spring beginning in the southern hemisphere, most of the surface outside the south polar region had been shrouded in dust. Dust storm activity picked up as the seasons changed and cold air from the south pole moved north toward the warmer equatorial air. Despite appearances, the entire planet was never involved in just one dust storm. Several large storms occurred at the same time, kicking dust high into the atmosphere where winds carried it over most of the planet.

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When Worlds Collide

The early universe teemed with galactic activity. With the cosmos a small fraction of the size it is today, collisions and mergers were commonplace and high-energy radiation would have lit up the sky.

We can still see those mighty collisions by probing billions of light-years away. Unfortunately, such distant objects appear so small and faint that little detail can be seen. If only astronomers could find a big collision nearby, they might learn what conditions were like when galaxies first appeared.

That's why Arp 220 holds such attraction. This object consists of two massive galaxies, each the size of our own Milky Way, colliding head-on. And at a distance of "only" 250 million light-years, it's the closest ultraluminous galaxy — one that radiates a hundred times more energy than our galaxy. Astronomers think the mega-merger triggered a huge wave of star formation, sent shock waves rumbling through intergalactic space, and could lead to the formation of a supermassive black hole.

Now an international group of researchers has used the Chandra X-ray Observatory to take the best x-ray image ever of the ongoing collision. "The Chandra observations show that things really get messed up when two galaxies run into each other at full speed," says team member David Clements of Imperial College, London.

The image reveals a bright central region at the waist of a glowing, hourglass-shaped cloud of million-degree gas. This gas forms a superwind that rushes out of the galaxy at hundreds of thousands of miles per hour. The astronomers also managed to pinpoint an x-ray source located in the nucleus of one of the pre-merger galaxies. A second, fainter source nearby may coincide with the remnant of the other galaxy's nucleus.

The two sources are relatively weak, however, supporting the idea that Arp 220's extraordinary luminosity results from a burst of star formation and not from matter accreting onto the black holes. That might change in a few hundred million years, when the black holes could merge. "The unusual concentration of x-ray sources at the center of Arp 220 suggests that we could be observing the early stages in the creation of a supermassive black hole," says team member Jonathan McDowell of the Harvard-Smithsonian Center for Astrophysics. — R. T.

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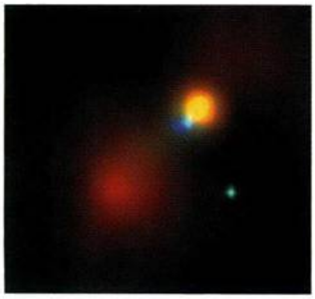


X rays flood from the superheated gas created during the titanic merger of the two galaxies in Arp 220. NASA/SAO/CXC/J. McDowell

Twins for a Distant Quasar

The Chandra X-ray Observatory has solved a puzzle concerning a double quasar 11 billion light-years from Earth. Because optical spectra of the twins were so similar, astronomers thought the pair was an optical illusion. Single quasars can appear split if a galaxy cluster lies between it and Earth, creating a gravitational lens. But 20 years of searching these twins produced no such object. Paul Green of the Harvard-Smithsonian Center for Astrophysics and his colleagues took x-ray spectra of the quasars and found they appeared distinctly different. "This may mean that the pair consists of two separate quasars," says Green, "though the mystery of how they can have identical optical spectra remains."

These twin quasars are not an illusion. NASA/SAO/CXC/P.Green, et al.

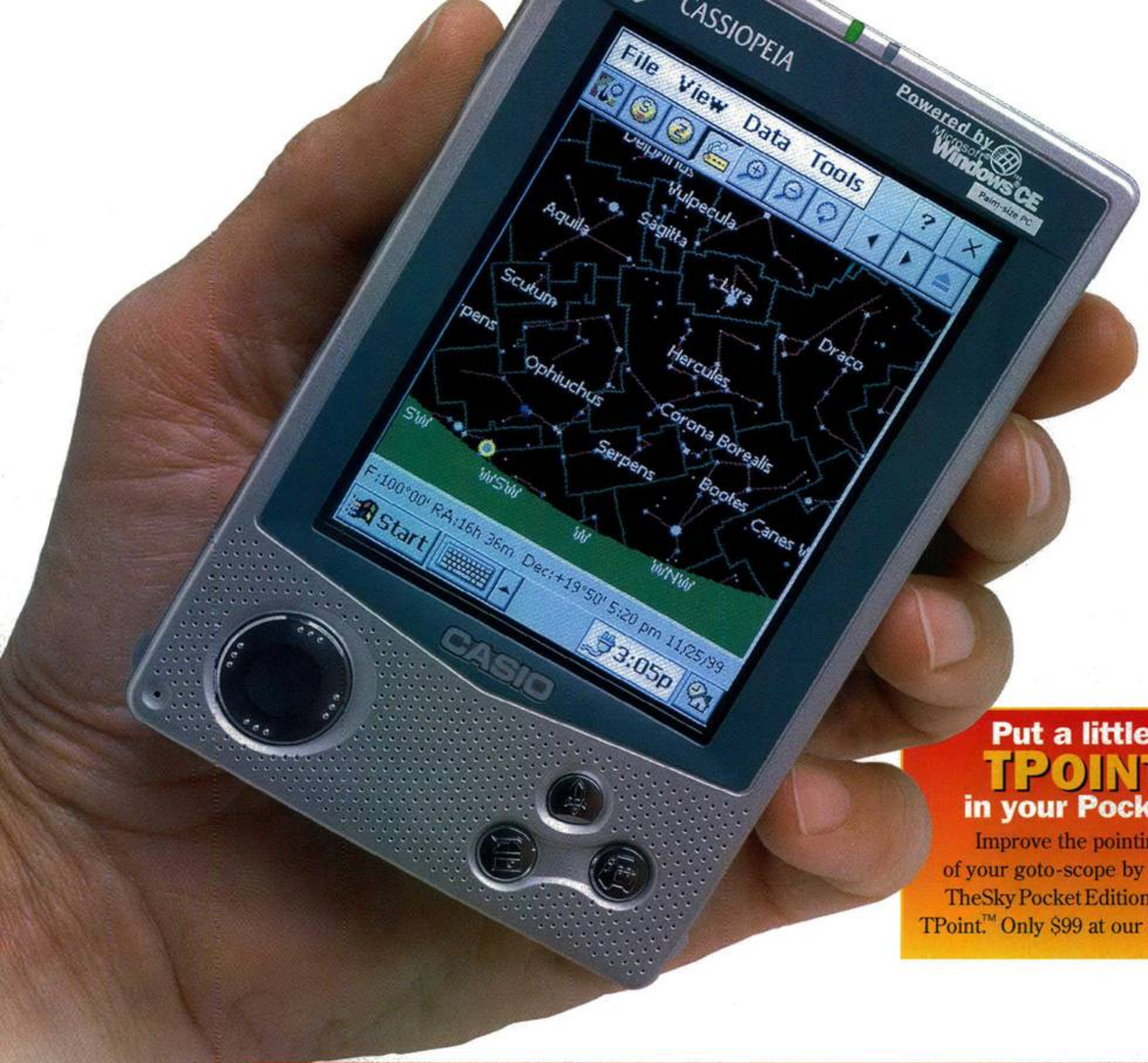
Jupiter's Family Grows by Eleven

Over the past several years, the gas-giant planets have traded places in the race for most moons. But the discovery of 11 new moons orbiting Jupiter, bringing its total to 39, vaults it well ahead. Astronomers Scott Sheppard and David Jewitt of the University of Hawaii and Jan Kleyna of the University of Cambridge discovered the satellites with the 3.6-meter Canada-France-Hawaii Telescope and the University of Hawaii's 2.2-meter telescope. All the moons have large, non-circular orbits inclined steeply to Jupiter's equator and revolve around the planet in the direction opposite to Jupiter's rotation. The researchers estimate that the moons are a mile or two in diameter.

Comet Borrelly Appears Hot and Dry

Astronomer Fred Whipple coined the phrase "dirty snowball" to describe a comet's nucleus. It turns out that at least some nuclei appear less snowy than anyone imagined. The latest analysis of data sent back by Deep Space 1 as it flew past Comet Borrelly last September shows no trace of frozen water on the comet's surface. Borrelly certainly has plenty of ice beneath its tar-black exterior, but any exposed to sunlight has vaporized away. "The spectrum suggests that the surface is hot and dry," says Laurence Soderblom of the U.S. Geological Survey, lead author of a report in the online edition of *Science*. "We know the ice is there, it's just well-hidden."

Comet Borrelly apparently has no ice on its surface. NASA/JPL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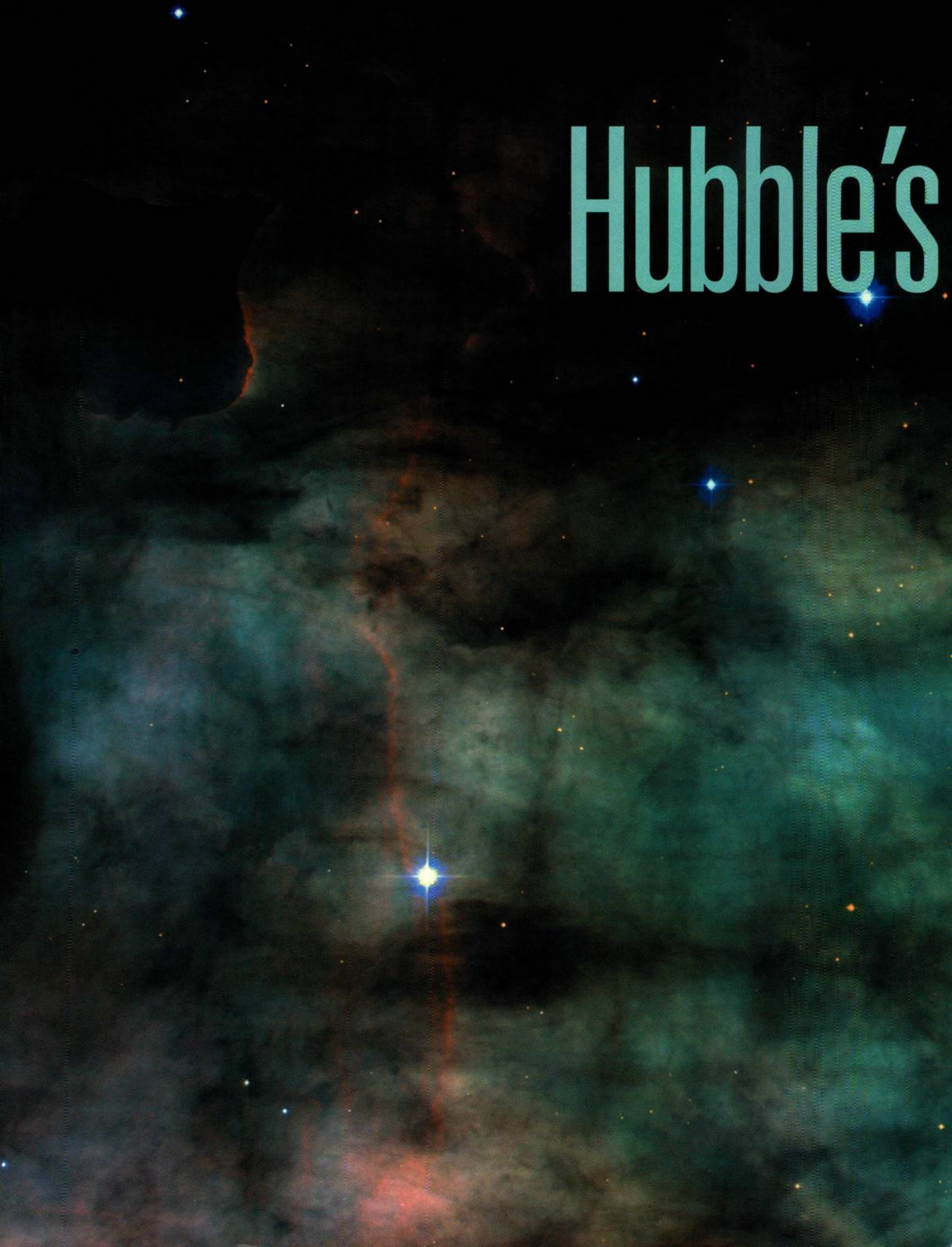
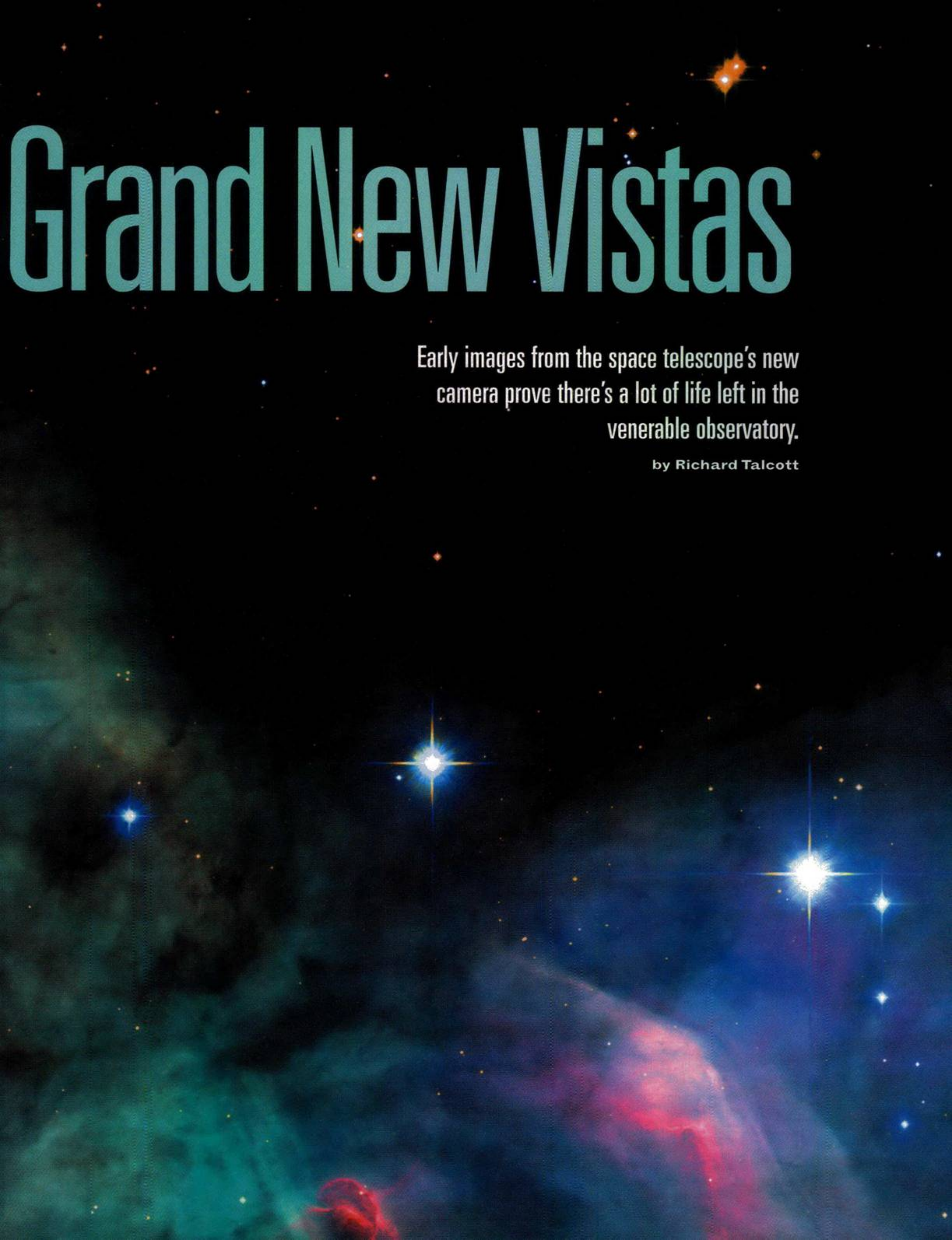

Hubble's

Grand New Vistas

Early images from the space telescope's new camera prove there's a lot of life left in the venerable observatory.

by Richard Talcott

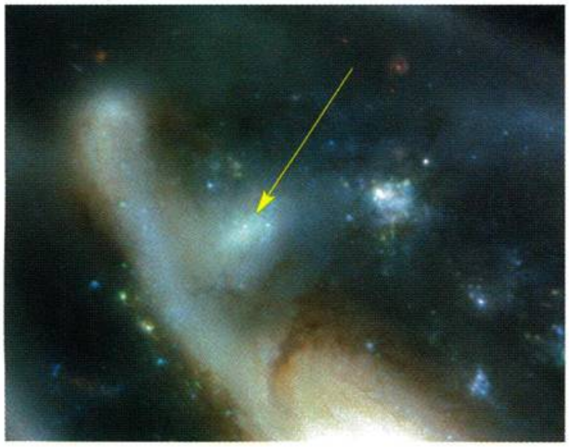


You might think that after 12 years in orbit, the Hubble Space Telescope would be plumb out of surprises. Yet like a child entering adolescence, Hubble stands on the threshold of an extraordinary new phase in its life.

The first sign of this awakening came in late April, when NASA released four images taken by the newly installed Advanced Camera for Surveys (ACS). "These are among the best images of the distant universe humans have ever seen," says Holland Ford of Johns Hopkins University, who led the team that developed the ACS. And best of all, the exquisite views of distant galaxies and starbirth in the Milky Way offer just a taste of what the refurbished Hubble can do.

For all this we can thank the visionaries at NASA, who knew enough not to leave a good thing alone. They designed the orbiting observatory with regular servicing missions in mind. Without that capability, astronomers would now be stuck with a fossil: optics that couldn't focus properly and technology more than 15 years out of date.

Previous page: Ribbons of gas and dust weave through the heart of the Omega Nebula (M17). Ultraviolet radiation from hot stars (beyond the image's upper right corner) evaporates regions of rarefied gas, exposing denser pockets that contain developing stars. This hotbed of starbirth lies 5,500 light-years from Earth in Sagittarius. All images: NASA, ESA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI), and the ACS Science Team



A galactic collision tore out the long tail seen in the Tadpole galaxy (right), located 420 million light-years away in Draco. Individual supergiant stars and star clusters pepper the spiral arms and debris tail. The two prominent clumps in the tail will likely become orbiting dwarf galaxies. The intruder galaxy that raised all the havoc lurks behind the disk (above, arrow). Roughly 6,000 galaxies appear in the image's background.

Hubble received its fourth visit from NASA in early March, when the space shuttle Columbia rendezvoused with the telescope. The 12-day mission saw a team of seven astronauts install the ACS, restore a dormant instrument to full operation, and replace the observatory's solar arrays, among other tasks.

But it's the Advanced Camera for Surveys that promises to keep Hubble at the forefront of astronomical discovery. The ACS, which replaces the Faint Object Camera, consists of three cameras in one: a wide-field camera, a high-resolution camera (with a smaller field of view), and a solar-blind camera, which filters out visible light to enhance its ultraviolet sensitivity. It also comes equipped with a coronagraph that can block the bright light from quasars and stars, for example, to examine faint objects nearby. All four of the images shown here were taken in the camera's wide-field mode.

The ACS has more than twice the field of view, twice the resolution, and five times the sensitivity of Hubble's current Wide Field and Planetary Camera 2. "That means a single ACS image can capture more objects in more detail and at a faster rate than ever before," says astrophysicist Frank Summers of the Space Telescope Science Institute.

This point was driven home in an image of UGC 10214 (pages 32–33), a spiral galaxy nicknamed the "Tadpole." The galaxy's distorted shape arises from a tiny intruder, a blue galaxy faintly visible through the disk of the Tadpole. Tidal forces between the interloper and the much more massive Tadpole pulled out the long debris tail, which extends more than 280,000 light-years.

The backdrop of more distant galaxies seen in the image proved to be an unexpected bonus. Astronomers have counted some 6,000 galaxies in the background, twice as many as appeared in the famed Hubble Deep Field. Even more impressive, the ACS image took 8.3 hours of exposure time — one-twelfth that of the Deep Field. The most distant galaxies visible lie 12 billion to 13 billion light-years away and rank among the most distant ever seen. And they are just the tip of the iceberg. "ACS will allow us to push back the frontier of the early universe," says Ford. "We will begin to enter the 'twilight zone' period when galaxies were just beginning to form out of the darkness that followed the cooling of the universe from the Big Bang."

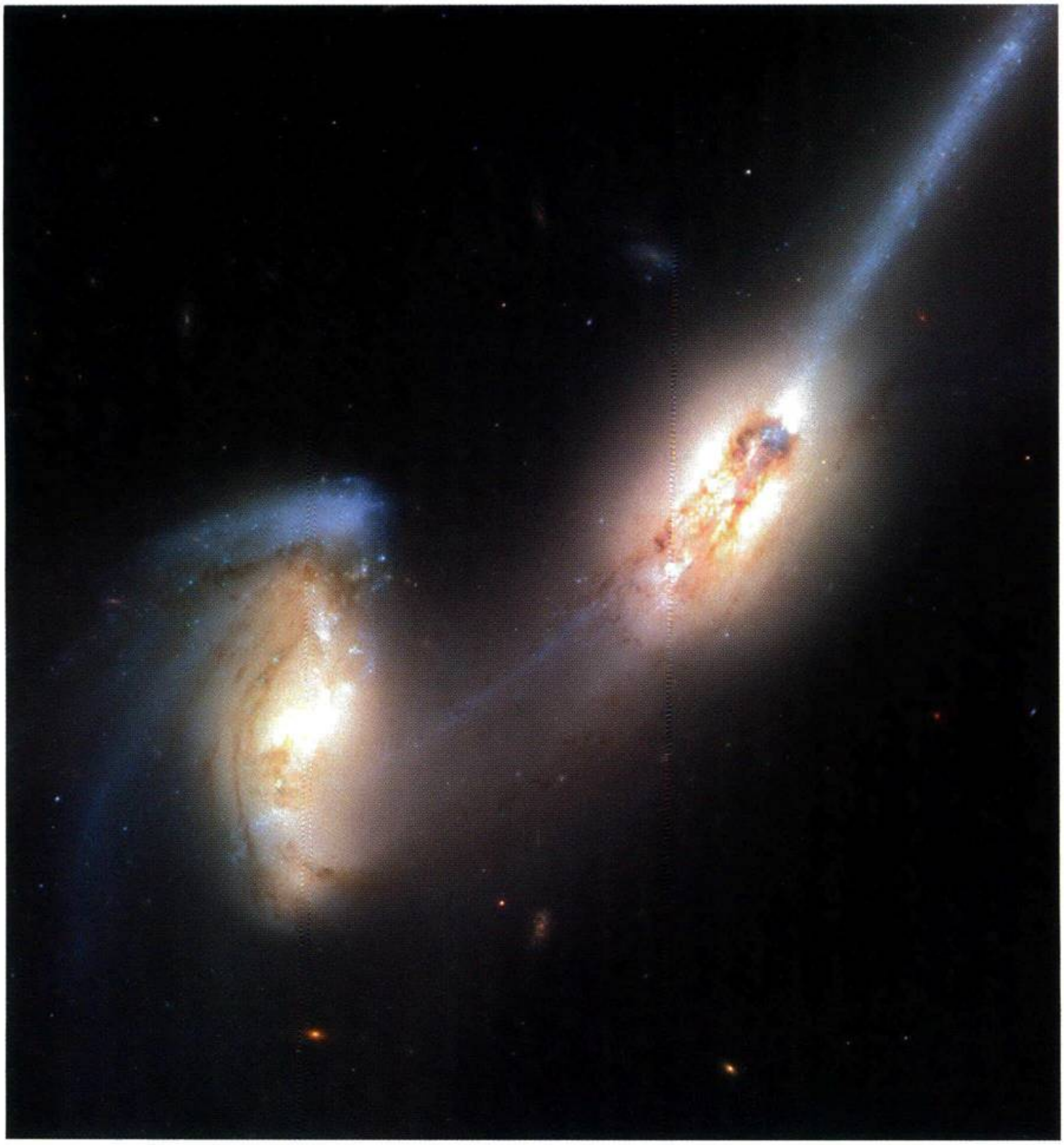
Hubble captured another pair of interacting galaxies, designated NGC 4676 (page 36). The rounded disks and long tail-like streamers suggested two mice playing to the Russian astronomer Boris A. Vorontsov-Vel'yaminov, and they have been known as the "Mice" ever since. Computer simulations by Joshua Barnes of the University of Hawaii and John Hibbard of the National Radio Astronomy Observatory show that the galaxies are in the early stages of encounter. They apparently sideswiped each other about 150 million years ago and are now heading back for a second, closer pass. It took the researchers a month of trial and error — mostly error, according to Barnes — to reproduce the Mice. The simulation predicts that the galaxies will merge into a single giant elliptical roughly 400 million years from now. A similar fate may await our own Milky Way Galaxy in several billion years, when we collide with the massive Andromeda Galaxy.

Hubble also targeted two regions in the Milky Way. An image of the Omega, or Swan, Nebula (M17) reveals a watercolor tapestry of glowing gas interlaced with dark dust all cradling scores of newly born stars — and likely embryonic planetary systems (pages 30–31). Powerful ultraviolet radiation from bright young stars sculpt the nebula's delicate tendrils. A crimson sea of glowing hydrogen gas surrounds the giant pillar of gas and dust known as the Cone Nebula (NGC 2264), seen at left. Ultraviolet light from hot stars located beyond the top of the image is slowly eroding away the nebula.

It won't come as a surprise to learn that astronomers plan to make the ACS Hubble's new workhorse. It will probe the universe's earliest galaxies, study the relation between supermassive black holes and galaxies, analyze distant supernovae to learn more about the mysterious dark energy that apparently permeates space, and even take a census of Kuiper Belt Objects in our solar system.

In addition to installing the ACS, Columbia's astronauts also reawakened the Near Infrared Camera and Multi-Object Spectrometer (NICMOS). It had been dormant since January 1999, when the frozen nitrogen used to keep its infrared detectors very cold finally evaporated. The astronauts fit NICMOS with an experimental cryogenic system that has cooled it to a temperature of –333° Fahrenheit (–203° Celsius), and the camera has begun to study the cool, dusty regions

The Cone Nebula (NGC 2264) fights a losing battle against intense ultraviolet radiation emanating from massive stars beyond the top edge of this image. The radiation erodes the edges of the cloud, liberating gas into the relatively empty space surrounding it. Ultraviolet light then excites the gas, causing it to glow with hydrogen's characteristic red color. Over millions of years, only the nebula's densest regions will survive. The Cone lies 2,500 light-years away in Monoceros.



of space once again. The first results from NICMOS should come out in early June.

The biggest change in Hubble's outward appearance came with the installation of new rigid solar panels. Some 45 percent smaller than the previous set, the more efficient units produce 27 percent more electrical power and have doubled the amount available to the scientific instruments. The astronauts also installed a new Power Control Unit, which distributes electricity from the solar panels and batteries to the observatory, and replaced one of the Reaction Wheel Assemblies used to help point the telescope.

Hubble pulled through the servicing mission in great shape and seems destined for several more years of flawless operation. As the newly revitalized space telescope prepares to enter its teenage years, we can only guess at what surprises it holds in store. ▣

Debris tails and a frenzy of star formation testify to the tidal forces generated when these two galaxies passed near each other. Nicknamed the Mice (NGC 4676), the galaxies also show streams of material flowing between them. The pair will eventually merge into one giant galaxy. The Mice lie 300 million light-years away in the rich Coma Cluster of galaxies.

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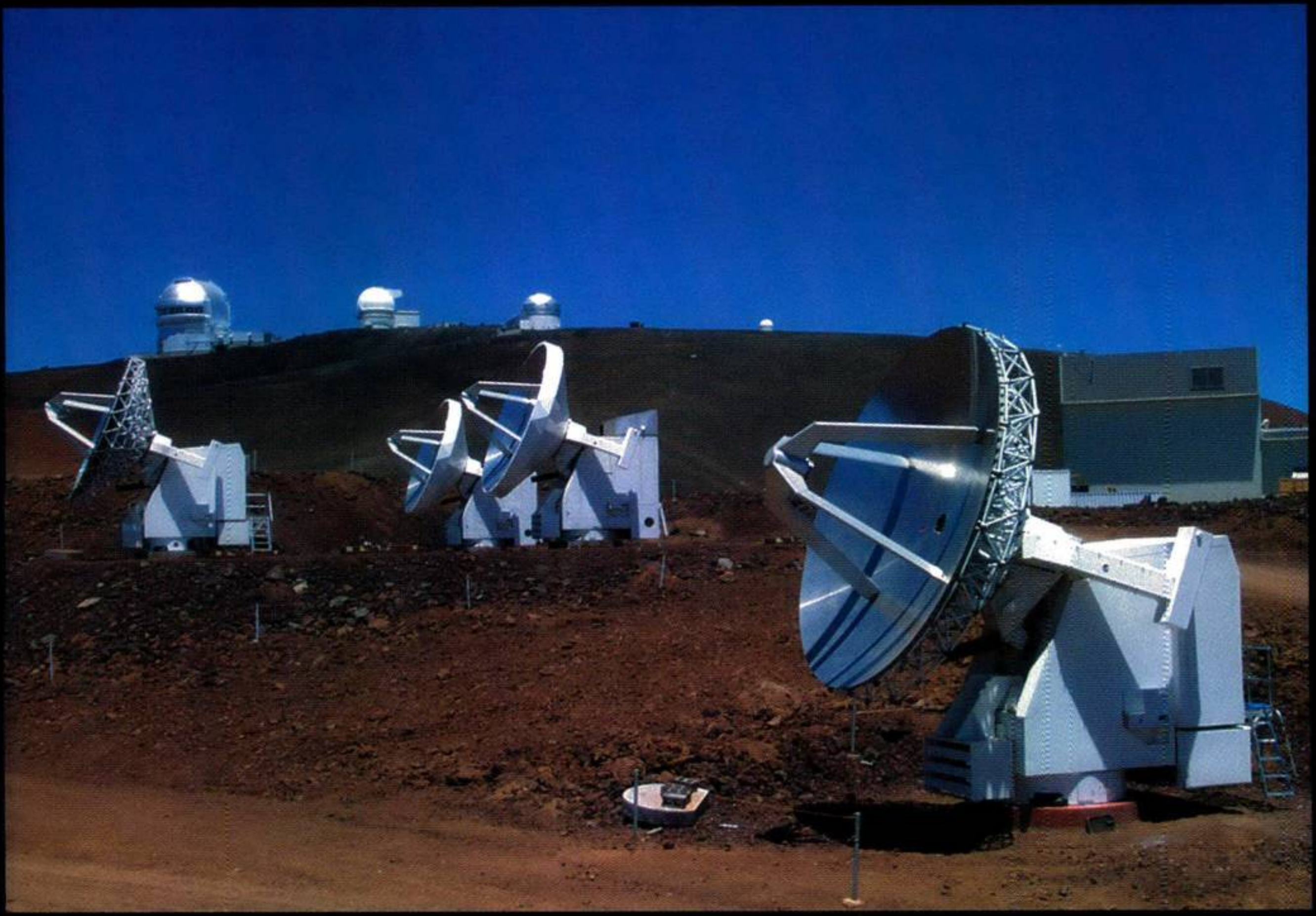

INFRARED

A new observatory for Mauna Kea will capture precision data from the far infrared wavelengths — undetectable to human eyes.

by Angela Swafford

In some corner of the nearby universe, within a star named IRC10216, the two atoms of a high-energy CO molecule spin wildly around each other, cavorting through a dusty, opaque realm. As it dances, the molecule emits a radio signal that travels through the universe at a frequency higher than 600 GHz. Crossing the interstellar medium, the signal reaches Earth, penetrating the atmosphere at a region low in water vapor. Gliding over the Pacific Ocean, the tiny alien messenger skims the top of Hawaii's Mauna Kea volcano and lands at the aluminum surface of one of the eight 6-meter antennae of the new Submillimeter Array Observatory (SMA). The collision sends the signal flying back to a secondary mirror above the dish, which in turn bounces the traveler down a shaft to a series of mirrors, and finally into a receiver.

Shooting through the 1.5mm aperture of a tiny gold-plated copper feedhorn, the alien information slams into a niobium super-conducting chip. The tiny filament is nested inside a liquid helium-fed cryostat kept at 4° Kelvin (–450° Fahrenheit) inside a thermally shielded vacuum chamber. Here, within this mixing device 5,000 times thinner than a human hair, the space signal is merged with a locally generated radio frequency and converted to a 5-GHz signal. It then is fed into a sophisticated fiber optic cable, run through a correlator, and manipulated by a complex cascade of mathematics, to finally reveal what it knows about the chemistry of the cosmos.

All photos: Harvard University

Such was the moment of truth taking place during one of SMA's initial tests (after a first light that looked at the moon in 1998) when a group of tense astronomers and engineers stared at the peaks and valleys of the CO spectrum generated by IRC10216 on their computer screens.

Conceived and designed as a state-of-the-art radio telescope in the submillimeter band (which houses wavelengths ranging from 1 to 0.3 mm), the SMA is a one-of-a-kind scientific tool to observe in the region of the electromagnetic spectrum ensconced between 150 and 900 GHz, near the far infrared. This last frontier in ground-based radio astronomy — in a realm undetectable to the human eye — brings us information about the microchemistry, temperature, and motion of the universe's earliest moments, as well as those of neighboring planets, dust clouds, and protostars.

Conventional wisdom had it that you could not see the submillimeter band from the ground because of the significant opacity of atmosphere. But huge advances in receiver technology have converged in the tools for radio astronomy, climaxing in the SMA that stands atop Mauna Kea. The observatory is a $70-million-plus partnership between the Smithsonian Astrophysical Observatory and Taiwan's Academia Sinica Institute of Astronomy and Astrophysics. "When completed in the summer of 2002, the SMA will consist of eight movable antennae that will work in concert as an interferometer," says James Moran, director of the SMA Observatory. "We will be able to form four concentric arrays called Reuleaux triangles, which are basically equilateral triangles with curved sides. The arrays will vary in aperture between 9 and 500 meters. There will be a total of 24 pads and the antennae will be moved according to the project at hand, to make the most efficient use of the configuration," says Moran.

SMA project scientist Paul Ho, who is based in Cambridge, Massachusetts, explains interferometry: "It's like taking a large mirror and breaking it into smaller pieces. Since it would be very hard to manage a huge mirror, what you do is use the pieces to reconstruct the image back into a whole."

The interferometer, coupled with its fine-tuned receivers, will give the SMA a resolution of one arcsecond, making it the world's most sensitive ground submillimeter telescope — at least until an international mega-project called the Atacama Large Millimeter Array (ALMA) begins operations in Chile in 2009 (see "The Megascope," page 41). Chile and Mauna Kea are two of the best places on Earth to observe in the submillimeter band, away from its main enemy, water vapor.

Five of the eight 50-ton antennae that will make up the SMA are already in place in the thin air of Mauna Kea's Submillimeter Valley, some 100 feet below the reddish elevation that supports the massive optical telescopes of Keck and Subaru. A sixth mount sits inside its hangar on the mountain. One more mount was shipped in September from Haystack, Massachusetts, and the last one was to travel to Hawaii this spring.

Each mount leaves Haystack on a flatbed truck that takes 14 days to traverse the country to Seattle. Here it goes on board a cargo vessel and makes the crossing to Honolulu in 12 days. A smaller barge places it at Hilo, in the Big Island, and then it's up the Saddle Road to Mauna Kea's summit. Most times the odyssey is uneventful. Yet accidents have occurred. Once the truck drove under an underpass that was too tight, and the drivers had to let air out of the tires, shearing a rivet or two off the tarp. On another occasion, the mount tipped off the truck and fell to the ground, causing a two-month delay.

On this afternoon, the bulky but graceful white frameworks of antennae 2, 3, 4, 5, and 7 are silhouetted against the still sky of Mauna Kea's sunset. The architecture of the dishes is still visible,

What the SMA Will Tell Us

Submillimeter wavelengths are particularly sensitive to cold dust emission and molecular spectral lines, which become increasingly more abundant and stronger in this band. The SMA Observatory aims to take advantage of these facts. In addition, it will exploit interferometry to achieve the best possible angular resolution for these wavelengths.

Single dish telescopes have already discovered "debris disks" around nearby young stars using submillimeter observations. The amount of mass in these debris disks corresponds to about that of the moon. With the SMA, we hope to image the morphological structures within such disks, perhaps gaps or condensations within the disks. This is pertinent to the question of planet formation. Since planets are solid opaque bodies, tiny at interstellar distances and very cold, they are difficult to detect directly. However, if they gather dust clouds as condensations around themselves, or if they influence disk structure through gravitational pull, then we should be able to detect them indirectly with the SMA. Only the SMA will have the resolution and sensitivity for such studies in the next decade.

As the universe cooled after the initial Big Bang expansion, matter began to form. The earliest coalescing structures could be galaxies undergoing the first star formation. The "early" universe would appear to us at very high redshifts. However, the peak of its radiation would be redshifted into the millimeter/submillimeter bands. We have used single dish telescopes in the submillimeter band to identify targets for SMA observing. We plan to image these candidates to measure their positions and to study their structures in order to identify them with specific objects that can be seen in the optical range. The SMA could be a unique tool for observing the earliest activities of the universe.

Single dish telescope studies confirm that at submillimeter wavelengths, many spectral lines become detectable. The SMA holds great promise for observing the line emission from many molecules at high angular resolution. If we think of the structure of the disks or clouds or galaxies that we wish to study as onion-like, then the various molecular lines can be thought of as special tags to specific layers within this "onion."

Using the SMA, we will study star formation, planet formation, galaxy formation, winds and outflows from young stars, and explosive activities in the center of galaxies.

Paul Ho, a researcher based in Cambridge, at the Harvard-Smithsonian Center for Astrophysics, is the project scientist for the Submillimeter Array Observatory.

Workers put the finishing touches on an antenna before it's placed on Mauna Kea.

A mount fell from a truck during shipping, and the accident caused a two-month delay.

Once the antennae arrive in Hawaii, they still require a good deal of assembly.

their 72 panels supported by a latticed structure of hollow carbon fiber struts and steel nodes as light as it is strong.

Exposed to the Hawaiian elements, the antennae must indeed be strong.

"One of our biggest challenges with respect to the antennae is to keep them in exact alignment," says astronomer Antony Schinckel, Director of Operations in Hilo, Hawaii, who used to work at the Parkes radio telescope in Australia, which was portrayed in the movie *The Dish*. "If even the slightest wind moves two telescopes with respect to each other when they are working, that's really bad news. We can't allow them to move, not even a fraction of a millimeter. So these dishes have been designed to be stable in a wide range of environmental conditions."

Armed with a screwdriver, mechanical technician Les Shirkey inspects the surface of one of the dishes.

"Even though the mounts are built in the mainland, we assemble the dishes here," says Shirkey, who went from building nuclear weapons for the U.S. Department of Defense to putting radio telescopes together. "Our main concerns are to protect the panels from temperature changes, ice, and bombardment from larger pebbles, so we will point them away from any strong winds. We also need to make sure they are perfectly aligned with respect to each other, so we monitor the slightest changes in orientation through a computer."

Within the frame of each mount is a carrousel or dewar with space for eight receivers with detectors specialized in capturing certain chunks of frequencies between the 170 and 900 GHz submillimeter band. The location at Mauna Kea allows for observing 40 percent of the signals that come between the wavelengths of 600 and 900 GHz, where the atmosphere is normally opaque.

Two more empty dewars sit at Cambridge's receiver lab of the Smithsonian Astrophysical Observatory, waiting to be fitted with the ultramodern detectors and the oscillators that will generate the local signal to be merged with the extraterrestrial radiation.

"We plan to build two receivers to do polarization studies," says Ray Blundell, electronic engineer and head of the receiver and antenna group. "But the key to the whole array is the tiny super-conducting niobium mixer chip sitting inside each detector, designed here and made for us by the Jet Propulsion Laboratory in Pasadena, California. It is barely a square micron in size, and we must keep it at –450° F or the superconducting material won't work. So we have designed a series of shields to keep it not just cold but in a vacuum. This really is cutting-edge research." Indeed, from the

The Megascope

At 16,400 feet above the sea in the spectacular plateau of Llano de Chajnantor, in Chile's Atacama Desert, breathing is difficult, walking is slow, and dehydration is a constant threat. Yet, this is the perfect place for radio astronomy, and the future home of the Atacama Large Millimeter Array, ALMA.

An international partnership between the European Southern Observatory, the National Radio Astronomy Observatory (NRAO), Japan, and several astronomical institutions throughout Europe and Chile, ALMA plans to build the largest radio telescope in the submillimeter band. The project calls for a total of 64 antennae with a diameter of 12 meters (39 feet), possibly coming into operation by the end of the decade.

Says Ray Blundell, head of the receiver and antenna group of the Submillimeter Array (SMA), "ALMA is building essentially the same thing the SMA did, only bigger. It is going to be able to do the things we can do, but more quickly. Also, it will detect fainter objects, because its collecting area will be bigger. The array will be able to expand its antennae about five miles. ALMA will have eight times as many antennae as the SMA, and each antenna will cover four times the area, so it will be many times more sensitive. But the SMA is a pioneering instrument."

At this point, a contractor in Santa Clara, California, is building prototype antennae, largely made of carbon fiber reinforced in plastic. These will be completed and delivered to the NRAO Very Large Array (VLA) site near Socorro, New Mexico, for tests.

ALMA hopes to achieve a resolution of 10 milliarcseconds, 10 times better than the SMA, VLA, and the Hubble Space Telescope. *— A. S.*

Receivers that capture information in the infrared await companions — and action.

far reaches of a molecular cloud, it all comes down to rest on the shoulders of the smallest of filaments.

Up on Mauna Kea, as it leaves the receiver within the mount, the foreign radio frequency is fed through a special fiber optics cable that won't deform with changes in temperature, traveling underground and into the main building, to a correlator room. A tangle of flat gray cables crisscrosses the room, which is crowded with electronics and walls covered in a thin mesh of copper to prevent interference from other radio frequencies.

After a complicated series of mathematical manipulations, the final product is digitized and delivered to the computer screens, where it takes shape as a spectrograph, and eventually, it will generate three-dimensional maps of pieces of sky. These maps will be critical given the enormous tasks intended for this new workhorse. The observatory will be used to study everything from astrochemistry to dust spectra — from dynamics, excitation, and structural formation of molecules — in addition to its ultimate goal — to make a giant grid of the sky.

"Different molecules transmit at different frequencies, and different molecules would be excited in different regions," says Ho. "So, whatever energy the molecule has is translated into a certain motion. The other thing is that the bulk of the universe is empty and cold. And the bulk of that energy comes out probably in the far infrared, the tail of which would be visible in the submillimeter. It would be important to track that because there are no other instruments that would have the angular resolution at the peak of the radiation curve." When up and running in full, the SMA will also look at how planets have formed, and probe the behavior of stellar disks, the motion of matter falling into a black hole, and the thermal emissions from tiny dust particles in clouds.

"We can already see fluctuations in temperature of one one-hundredth of a degree," says Moran. "And we can study the CO absorption from planets like Venus, Mars, and Saturn. Analyzing data, we will be able to tell what the temperature is in the atmosphere of the planet as a function of height, from zero to forty kilometers, almost as if you'd inserted a thermometer."

The night in Mauna Kea has grown considerably colder. The blackout at the summit is strictly enforced, making it hard to see the bulk of even the closest telescope. Somewhere inside each mount of the SMA is a motor that whirrs and purrs, as an invisible hand orders the dishes around.

Turning his flashlight off, Schinckel walks inside the building and up the stairs to a brightly lit control room where three astronomers are staring at computer terminals, with bags of candy and cans of soda at their sides to ease the long working night. Tonight is mostly for calibration. Still, the eager scientists expect to catch a glimpse of some interesting chemical signature inside a certain star-forming region. Soon enough, though, the three 24-hour clocks that monitor the time in Hawaii, Taiwan, and Cambridge say it is time to head back.

Gradually, and then more decidedly, the sun shines behind the summit, revealing white patches of snow that rebel against the heat in June. Mauna Kea's lonely ridges and reddish slopes reveal the striations left behind by ancient glaciers.

"We're the so-called thirteenth telescope," says Moran. "The last telescope to be allowed on Mauna Kea in the 20th century. Unfortunately we caught some heat from native Hawaiians and environmentalists. They say we are not one but eight telescopes. The ALMA project leaders were initially interested in bringing their project to Hawaii, and of course someone heard they were planning to build sixty-four." Many Hawaiians feel their mountain has been desecrated in the name of science, and its sacred dome is now littered with observatories visible from everywhere on the island. Some would like to see the telescopes dismounted. Environmentalists claim endangered arthropods and lichens should be left alone. And astronomers don't want to lose one of the best skies on the planet.

A new master plan proposes the construction of several more telescopes. Still, none have really been approved, so the dispute is far from over.

In this dying afternoon, though, everything looks normal. Once again, day crews switch jobs with the night shift and head back to the comforts of the dormitories and restaurant 5,000 feet below. Bathed in pink hues, the world's largest concentration of astronomical tools seem to exist in a mode of their own. Oblivious to the controversy that surrounds them, one by one they open their eyes, ready for one more night of sifting through the universe. **A**

Angela Swafford, who lives in Miami, is a freelance writer. She recently studied science at MIT on a Knight fellowship.

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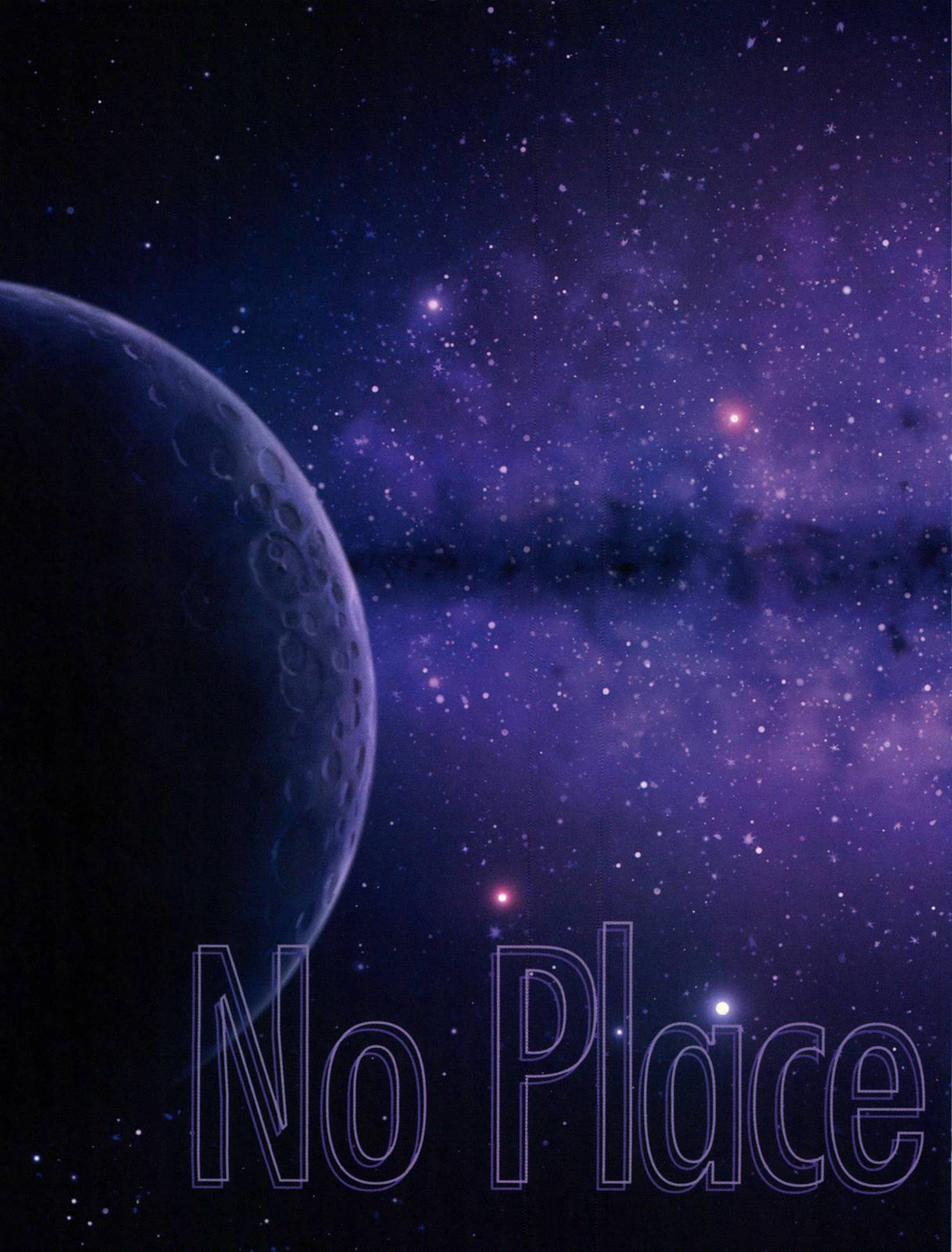

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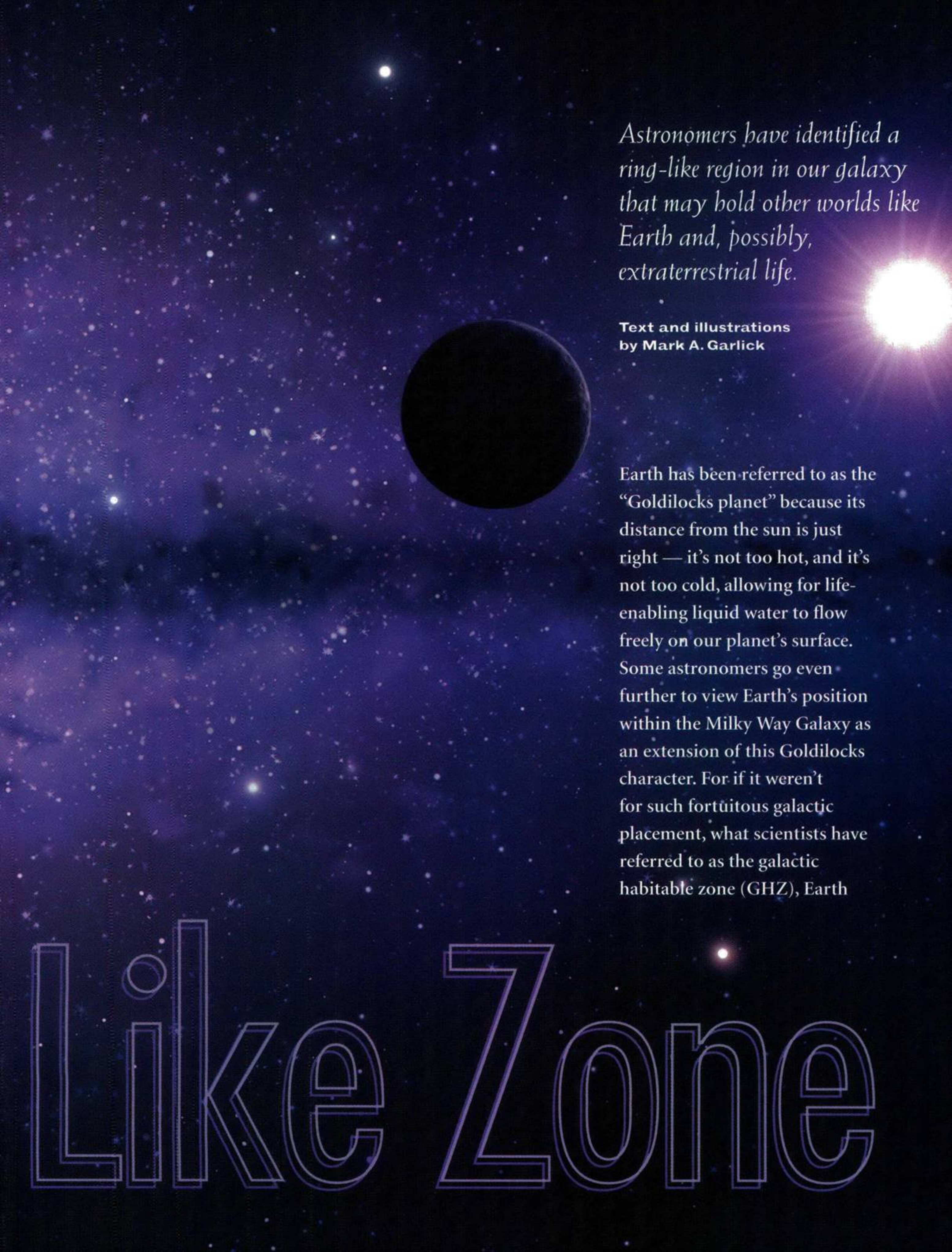


Like Zone

Astronomers have identified a ring-like region in our galaxy that may hold other worlds like Earth and, possibly, extraterrestrial life.

Text and illustrations by Mark A. Garlick

Earth has been referred to as the "Goldilocks planet" because its distance from the sun is just right — it's not too hot, and it's not too cold, allowing for life-enabling liquid water to flow freely on our planet's surface. Some astronomers go even further to view Earth's position within the Milky Way Galaxy as an extension of this Goldilocks character. For if it weren't for such fortuitous galactic placement, what scientists have referred to as the galactic habitable zone (GHZ), Earth

Previous page: On the outskirts of the galaxy stellar density drops, as does the star formation rate and therefore nucleosynthesized "metallicity." These remote stars form tiny, Mercury-like planets — too small to host complex life.

Right: The galactic halo is rife with globular clusters, containing the oldest and most metal-poor stars in the Milky Way. Little starbirth occurs here and any terrestrial planets that form will be small mini-worlds that cool quickly, develop thick crusts, and lack sufficient gravity to hold life-nurturing atmospheres.

may well have been scorched by gamma-ray jets, blown away by stellar winds, blasted apart by supernovae explosions, or bombarded by countless comets and asteroids long ago.

In less than a decade, researchers have found nearly 80 planets orbiting just a handful of stars – all of which lie in the sun's neighborhood. These results have been cheered right across the astronomical community. For if such a relatively tiny region of space is rife with planets, this raises the probability that exoplanets are common throughout the galaxy, even across the universe. From there, it's just a baby step to believing that life might be common too. But if new research into the characteristics of the GHZ is correct, then terrestrial life-bearing exoplanets — if they exist — will not be distributed randomly across the Milky Way. These earthlike worlds will be limited to within a narrow annulus centered on the galactic core and containing the sun. Outside of this zone, some astronomers now contend, the Milky Way might be as sterile as the surface of the moon.

Getting to the Zone

The GHZ is a relatively new idea, as we shall see. But the concept of the Circumstellar Habitable Zone (CHZ), often abbreviated to just "habitable zone," first appeared in the scientific literature in the 1950s. Very simply, the habitable zone is defined as that region around a star where water — regarded by many as essential for life — exists in liquid form on the surface of a planet long enough to nurture the evolution of life. If the planet is too close to the star, water will evaporate and the planet overheats. If it's too far out, water freezes. The zone's definition varies from time to time and may not contain strictly all possible life-bearing worlds. For example, the jovian moon Europa is well outside the sun's habitable zone and yet is regarded by many scientists as one of the two most likely places in the solar system (the other being Mars) where extraterrestrial life might exist. The CHZ has its merits, and since the 1980s various researchers have considered extensions to this concept on the galactic scale.

For example, some believe that the sun's placement near the so-called co-rotation radius aided the development of complex life on Earth. The co-rotation radius is the distance from the galactic core where the orbital period of the sun around the core matches the rotation timescale of the galaxy's spiral arms. The spiral arms do not revolve at the same speed as the stars themselves, except near the co-rotation radius. Because the sun is so close to the co-rotation circle, this minimizes the number of times the sun crosses a spiral arm, thereby avoiding the infusion of a superdense stellar environment. This is important because perturbations from nearby stars could send some of the Oort Cloud's many cometary nuclei spiraling into the inner solar system to wreak havoc on Earth. If those perturbations come too regularly, as they would if the sun were far outside the co-rotation radius and crossed the denser spiral arms more often, then the development of life on Earth would have likely faced a fierce uphill battle.

But protection within the realm of the co-rotation radius is not the entire story. In July 2001, astronomers Guillermo Gonzalez, Donald Brownlee and Peter D. Ward — all from the University of Washington — published a paper in *Icarus* in which they looked at a much bigger picture.

The Elements of the Galaxy

The paper presents a study of how the Milky Way's chemical evolution possibly constrains the existence of earthlike planets in the galaxy. Stellar birth and death ultimately determine when and where chemical elements exist within galaxies. Some astronomers, like Gonzales, contend that earthlike planets can only form if interstellar birth clouds contain the "right stuff." And this notion is crucial to the development of GHZ theory — the chemical compositions of stars, and therefore planets, are intimately linked to galactic location.

The first stars ever consisted of little more than hydrogen, helium, and lithium — the main elements created in the Big Bang. When these seminal stars died, the elements forged within them through stellar nucleosynthesis — the nuclear reactions that keep stars balanced against gravitational collapse — were jettisoned into space. Later stars that formed from these ashes thus incorporated large quantities of heavier elements, or metals. As time goes on more and more stars die and pave the way for new stars, which then contain ever-higher metallicities. As a result of all this plus the gravitational dynamics of the Milky Way, our galaxy is now composed of four distinct components, each of which contain distinct stellar populations. The region where the sun resides is known as the thin disk — a flat pancake about 600 light-years thick — inside of which star formation is still active, and young, metal-rich stars abound. The second component, the thick disk, is about three times thicker and holds older stars containing fewer metals. The bulge that resides at the center of the galaxy is the third component. It contains a mixture of both young and new stars. Lastly, a halo of spherical star clusters surrounds the disk. These globular clusters contain the oldest and most metal-poor stars in the Milky Way, and harbor little, if any, star-producing nebulae.

The fact that stellar metal content, or "metallicity," is correlated with position and time within the galaxy is a key factor in the team's concept of a GHZ. Planets form at the same time as their parent stars, and thus reflect the metallicity of the nebulae that forge them. And, like stars, planets will also have compositions dependent on where and when they form within the galaxy. Old stars — formed from ancient material very poor in metals — ought to breed relatively low-mass terrestrial planets. Conversely, more recent generations of stars — formed from relatively metal-rich nebulae — should harbor comparatively high-

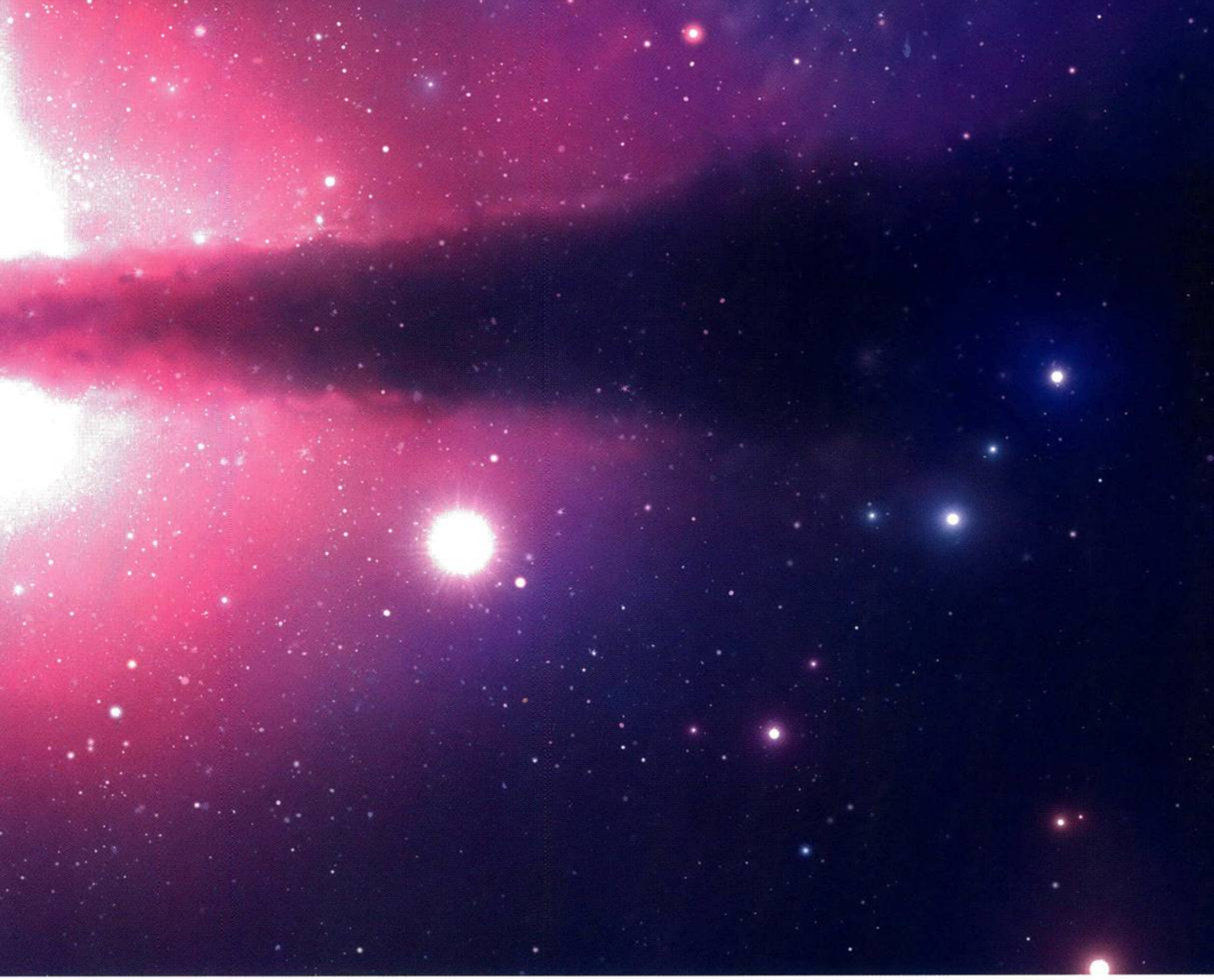
mass terrestrial planets. With this in mind, Gonzalez and his team entertained the issue of where among our galaxy's hundreds of billions of stars habitable planets would most likely arise.

Defining the Zone

Astronomers can narrow down the GHZ based on what they know about stars in various parts of the Milky Way. The stars in the halo and the thick disk may simply be too old to hold sufficient quantities of metals for any earthlike planets. With such a low metallicity, any terrestrial worlds that form will be small. These mini-worlds will cool quickly, develop thick crusts, and lack sufficient gravity to hold substantial atmospheres. A scant atmosphere wouldn't hold enough ozone to protect life from ultraviolet radiation, as is the case on Mars. And with a thicker crust, plate tectonics would not operate and the climate — whose long-term stability depends on the removal of carbon dioxide from the atmosphere by the subduction of surface rocks driven by plate movement — might become too unbalanced. So if the halo and thick disk stars are not made of just the right stuff, this leaves the bulge and the thin disk as the most likely territory for terrestrial worlds.

But according to Gonzalez and his team, they can pin down the GHZ still more precisely. Closer to the galactic core, stellar densities are higher, meaning that any stars there will undergo regular gravitational perturbations. And as we saw earlier, this could mean serious impact hazards for planets orbiting stars that are surrounded by cometary clouds. But perhaps more importantly, being up close and personal to overpopulated star systems also invites danger in the form of radiation from stellar winds, supernovae, or anti-matter and gamma-ray bursts emitted by the supermassive black hole residing in the Milky Way's nucleus. So Gonzalez excludes the bulge from the GHZ.

We are now left with only the thin disk, but not the whole of it. As you move along the disk toward the bulge, star formation rates increase and metals become correspondingly more abun-



dant — because with higher rates of star formation the recycling by nucleosynthesis is much faster. High-metallicity stars, in contrast to low-metal ones, form terrestrial planets that are too massive. Such monstrous planets naturally have more materials to work with — more iron for their cores and more water for their oceans. And due to differentiation, heavier metals like iron would sink to the planetary core while lighter substances like water would remain on the planet's surface or in the atmosphere. Consequently, if Earth, for example, were twice its radius, it would become a water world. Only Kevin Costner would feel at home on such a planet. Gonzalez thinks a world that's too sopping wet inhibits the development of complex life forms because the interaction of land and sea is — like tectonics — a crucial factor in habitable climate control.

So, close to the bulge is not lively real estate. And conversely, as we move toward the edge of the galaxy, far away from the core, stellar densities drop, as does the star formation rate and therefore metallicity. These stars, just like those in the halo and thick disk, will form planets too tiny to host the evolution of complex life.

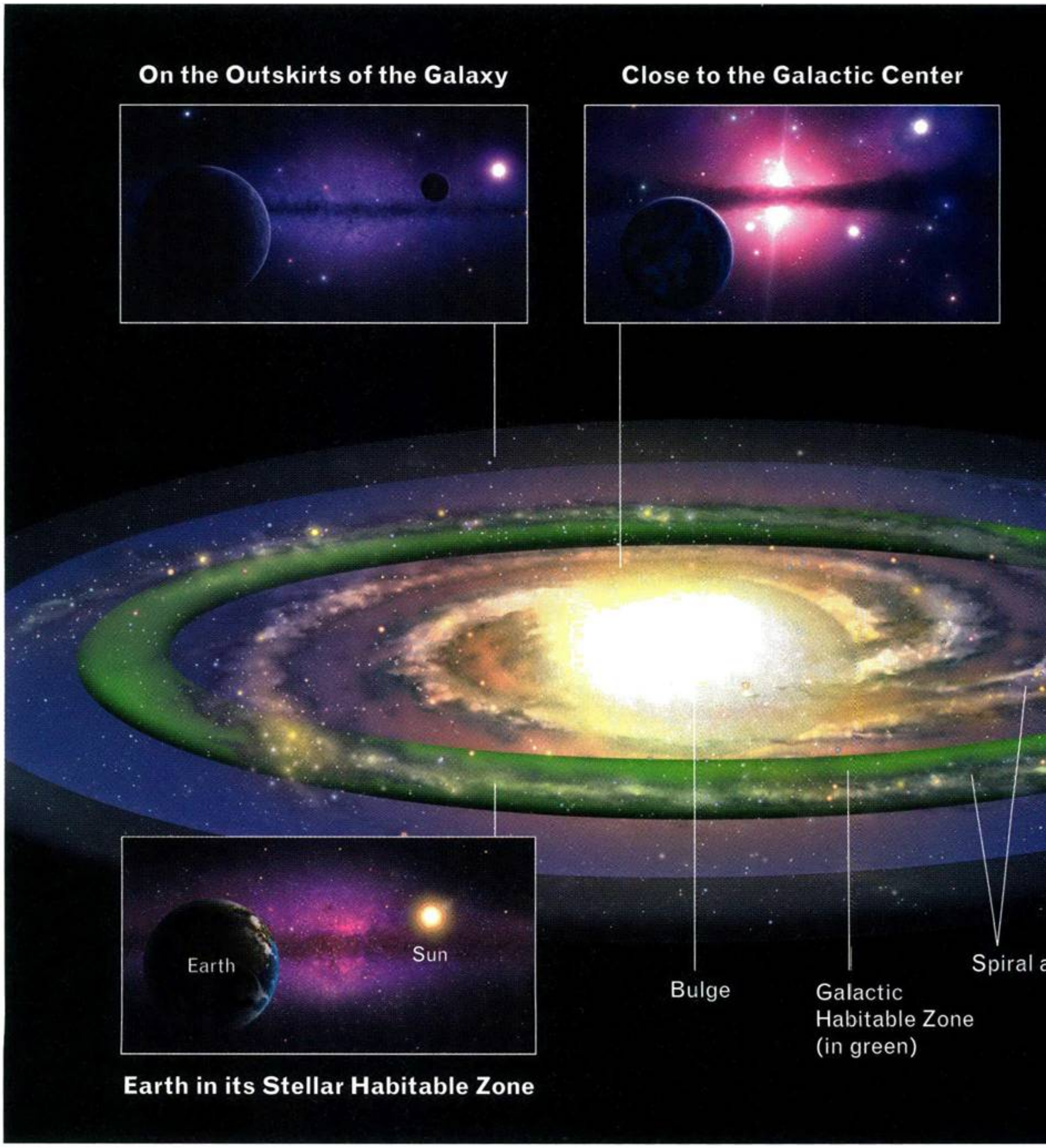
All this suggests that the stars most likely to support earthlike worlds lie in the thin disk, more specifically in an annulus (the inside of which is roughly 15,000 light-years from the galactic core, and the outside nearly 40,000 light-years) centered on the galactic core and encompassing the sun's orbit (with a mean distance of 28,000 light-years). This, then, is what Gonzalez and his team consider the true Galactic Habitable Zone: The stars here are Goldilocks stars. They are far from the hustle and bustle of the galactic core, and have metallicities that are just right — not too low and not too high.

The Extent of the Zone

There is not a great deal of evidence for GHZ theory because there are so many variables that come into play. Still, there is one interesting fact

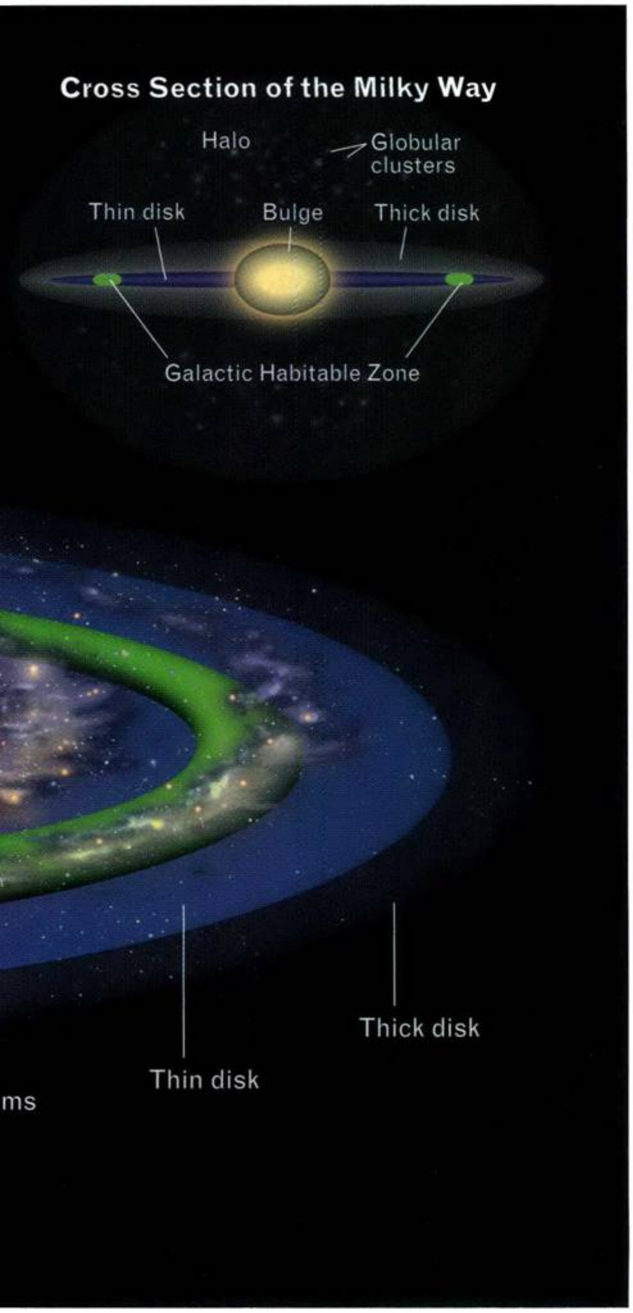
Planets near the galactic core would face constant assault among overpopulated star systems. Cometary bombardment, intense radiation from stellar winds, nearby supernovae, or gamma-ray bursts might sterilize emerging worlds.

The Milky Way's habitable zone may be limited to a narrow annulus about the galactic center. Our solar system lies within this ring and just so happens to host a planet "just right" for the development of complex life.


On the Outskirts of the Galaxy
Close to the Galactic Center
Earth
Sun
Earth in its Stellar Habitable Zone
Bulge
Galactic Habitable Zone (in green)
Spiral a

that supports the theory: Of all the stars so far found to harbor planets, almost none has less than 40 percent of the sun's metallicity. It was Gonzalez who found this correlation between planetary presence and high stellar metallicity. Some scientists think that these stars have high metallicities because they have swallowed planets that migrated inward, but that would require an unrealistically large number of kamikaze planets. Another thumbs up for Gonzalez and his team concerns a study made using the Hubble Space Telescope to search for planets that might transit across their parent stars, thereby dimming a star's light enough to reveal their presence. The study in question was concerned only with the stars in the globular cluster 47 Tucanae, which thrive in the halo and therefore outside the purported GHZ. The study found that these stars have metallicities lower than 25 percent solar. As old stars, this is expected. But crucially, not one was found to harbor a planet.

Gonzalez and his colleagues feel that in order for a terrestrial world to support life, its mass must lie within a very narrow range — from one-third to three Earth masses, possibly narrower still. And their best guess for a range in metallicity for an earthlike planet is between 20 and 200 percent solar. Because the metallicity of stars in the thin disk increases steadily toward the disk's center, this suggests that the GHZ, the region of optimal metallicity, extends for 10,000 or so light-years on either side of the sun's orbit. But, notes Gonzales, "the width of both the CHZ and GHZ will depend on the complexity of life one is dis-



cussing. Both are wider for simple life." Note also that the GHZ is time-dependent. As time passes, future generations of stars in the neighborhood of the sun will become more and more metal rich because of nucleosynthesis. As a result, the GHZ migrates outward with time.

The SETI Skeptics

GHZ research might impact the search for extraterrestrial intelligence (SETI), currently conducted at the SETI Institute in northern California. If there truly is a region within the galaxy that optimizes the probability of life-bearing planets then, arguably, the SETI Institute should conduct its searches within this zone.

"At the moment, Project Phoenix looks at sunlike stars that are within 150 light-years. In the next 10 to 20 years, we hope to extend this targeted search to perhaps 1,000 light-years. Even with this far greater reconnaissance, involving millions of stars, we are still looking relatively nearby, and therefore well within the annulus being proposed as most appropriate for ET's abode," explains SETI researcher Seth Shostak. So it seems that at least for right now GHZ research will have little impact on SETI work.

In any case, Frank Drake, the SETI Institute's director, remains unconvinced that the principle of a GHZ has any value whatsoever. "I, and many other people, think the whole thesis of the Galactic Habitable Zone is based on very limited data and much speculation about almost every important issue in the concept," he says. "So little is known about planetary-system evolution and cosmic influences on evolution that it wouldn't be hard to construct an equally appealing scenario almost the reverse of the one being discussed."

Another scientist who prefers a slightly less skeptical approach to the idea of the GHZ is British-born Emma Bakes, an astrophysicist who works for both NASA and the SETI Institute. One of the biggest assumptions that Gonzalez and his team make is that habitable planets will be earthlike, but Bakes feels that it is a mistake to conclude that life requires earthlike conditions. "It is a very shortsighted approach to look for life similar only to terrestrial life," she said. "Even though we use Earth as a paradigm for the blueprints of life, we must not allow it to narrow our vision of what might exist in environments radically different to our own planet. Life could form in giant gaseous planets, which have nowhere near the metal or rock content of the inner terrestrial planets."

Bakes may be correct. Still, we simply don't know if life could exist within the atmosphere of a gas giant. And it's worth noting that even gas giant planets may require high-metal environments in order to form. For example, one theory posits that Jupiter formed when a large planetoid of rock and ice — 10 to 20 times the mass of Earth — accreted around the sun and then began to pull in hydrogen and helium by virtue of its enormous gravity. If this is correct, Jupiter too owes its existence to the relatively high metallicity of its birthplace. It is also worth remembering, as already noted above, that virtually all of the gas giant planets found to date orbit stars with substantially high metallicities.

Even if it turns out that planet formation has little to do with metallicity, it remains improbable that life could exist and thrive on a planet, gas giant or not, too close to the galactic core. In short, if there is no outer boundary to the GHZ, there might, at the very least, be an inner one.

Mark A. Garlick is a freelance writer, illustrator, and astronomer based in England. He recently wrote and illustrated The Story of the Solar System. *See more of his work at http://www.space-art.co.uk.*

sky Show

august

Summer's best shooting stars: The Perseids reach their peak.

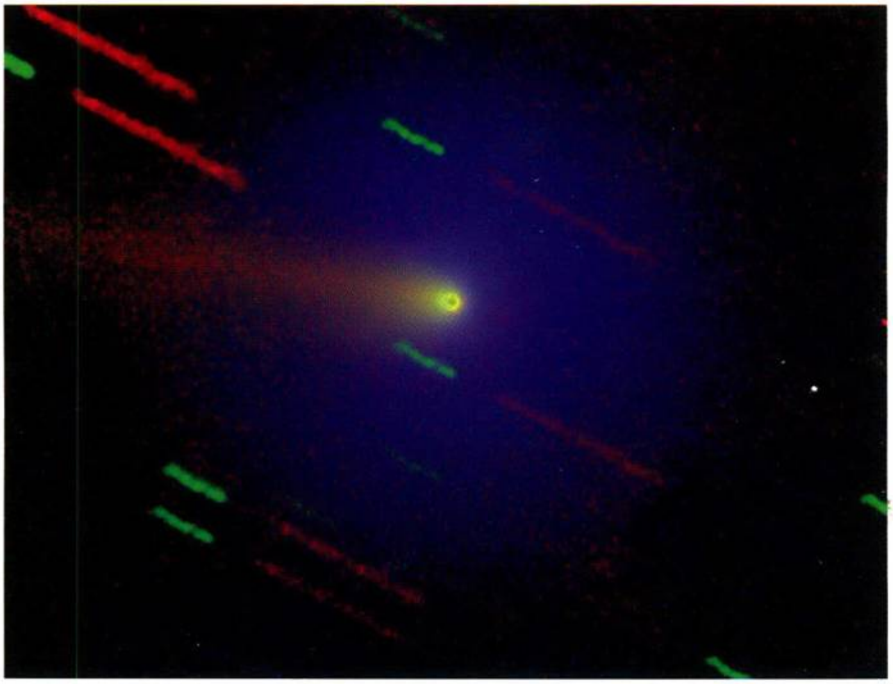
by Martin Ratcliffe and Alister Ling

▶ Skywatchers the world over eagerly anticipate the Perseid meteor shower. From a dark site you might see 60 to 100 swift streaks per hour crossing the sky. And you can't beat the mild nights of late summer for observing in comfort. So grab some blankets, sleeping bags, warm drinks and pitch camp under the stars.

The primary peak of the shower occurs at 6 P.M. EDT on August 12, so the Eastern Hemisphere is favored. On the other hand, it means that the Americas and Europe get two chances to see a pretty good shower, once before dawn on Monday morning and again during late evening and overnight into Tuesday August 13. During evening hours from a dark site you may see up to 30 streaks per hour, but only half as much if observing from an urban setting.

You may notice a bright point of light low in the sky amidst the post-sunset glow: This is Venus. At other times, our sister planet stands high above the horizon and shines on until midnight. A spotting scope will show Venus's phases, which start out the month as a smallish, out-of-round disk, but then move toward the "half-moon" look to 43 percent by the end of August. To see another celestial body in a phase, watch the crescent moon slip 6°, or roughly one binocular field, away to the north of Venus on Sunday evening, August 11.

A Perseid meteor streaks over Lewiston Lake in California on August 12, 1999. Donald Lammon



A mission is planned for a probe to visit the periodic comet Wirtanen. ESO/VLT

With the finder chart in this month's *Astronomy*, you'll be able to crack the tough nut that Neptune often presents for beginners. This distant gas-giant planet lies so far away that its tiny disk is easy to mistake for a star. But as luck would have it, Neptune crosses a part of the sky in Capricornus where it won't be lost in a maze of twinkling points of light. A 90mm (4-inch) telescope from the suburbs should easily capture the 8th-magnitude Neptune.

Not far from Neptune — at least as viewed from our earthly vantage point — you may spot the asteroid Iris. There are plenty of naked-eye stars here to help guide you to this lonely space rock. Some double stars appear to hang out in this same neighborhood, but in reality they are far, far away in the background.

Wouldn't it be neat to just look up in the sky with the naked eye and see a different star every night? Well, you can — it's known as the variable star Eta Aquilae, a bit below the bright blue star Altair. Altair itself is the foot of the great summer triangle, along with Vega and Deneb higher up in the sky.

August is prime time for star parties, most of which are held on the weekend closest to the new moon. This time around it's the weekend of August 10. These parties offer a great chance to meet other observers and to get a look through many different telescopes.

This month get your first glimpse of Saturn since last spring. But before you blast your eyeballs with its brightness, swing a bit south and have a look at periodic comet Wirtanen. It should be as bright as comet Petriew, which attendees at a star party discovered last year.

2002 August

1 Last quarter moon is at 6:22 A.M. EDT
Neptune is at opposition, 9 P.M. EDT (page 59)

4 The moon passes 2° north of Saturn, midnight EDT

5 Mercury passes 0.9° north of Regulus, midnight EDT

8 New moon is at 3:15 P.M. EDT

9 The moon passes 4° north of Mercury, 9 P.M. EDT

10 Mars is in conjunction with the sun, 6 P.M. EDT
The moon is at perigee (225,513 miles from Earth), 7:30 P.M. EDT

11 The moon passes 6° north of Venus, 6 P.M. EDT

12 Asteroid Pallas is at opposition, 8 A.M. EDT
Perseid meteor shower peaks (page 60)

15 First quarter moon is at 6:12 A.M. EDT

19 Uranus is at opposition, 9 P.M. EDT (page 59)

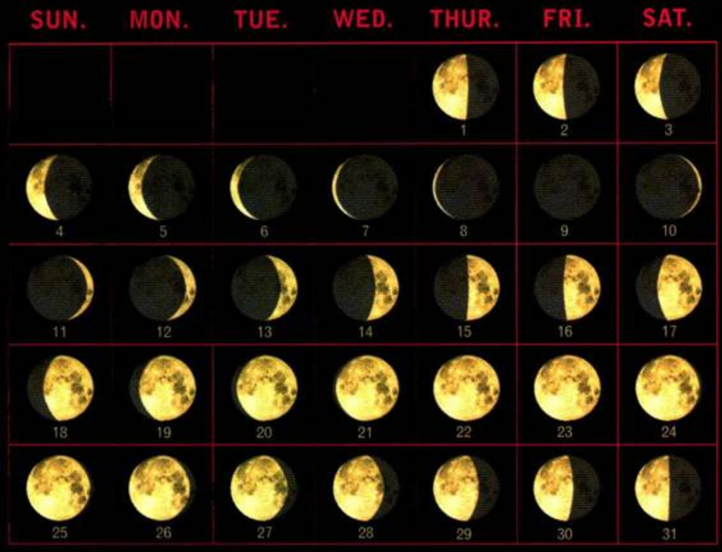
20 The moon passes 4° south of Neptune, midnight EDT

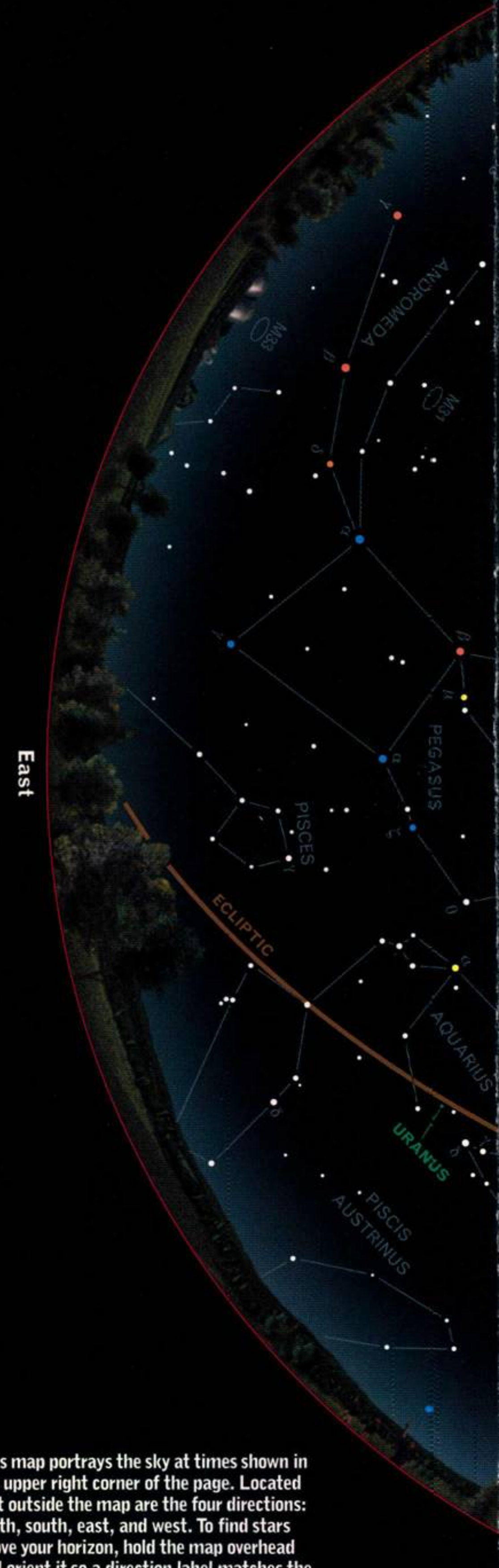
22 Venus is at greatest eastern elongation (46°), 9 A.M. EDT
The moon passes 4° south of Uranus, 10 A.M. EDT
Full moon is at 6:29 P.M. EDT

26 The moon is at apogee (252,087 miles from Earth), 1:41 P.M. EDT

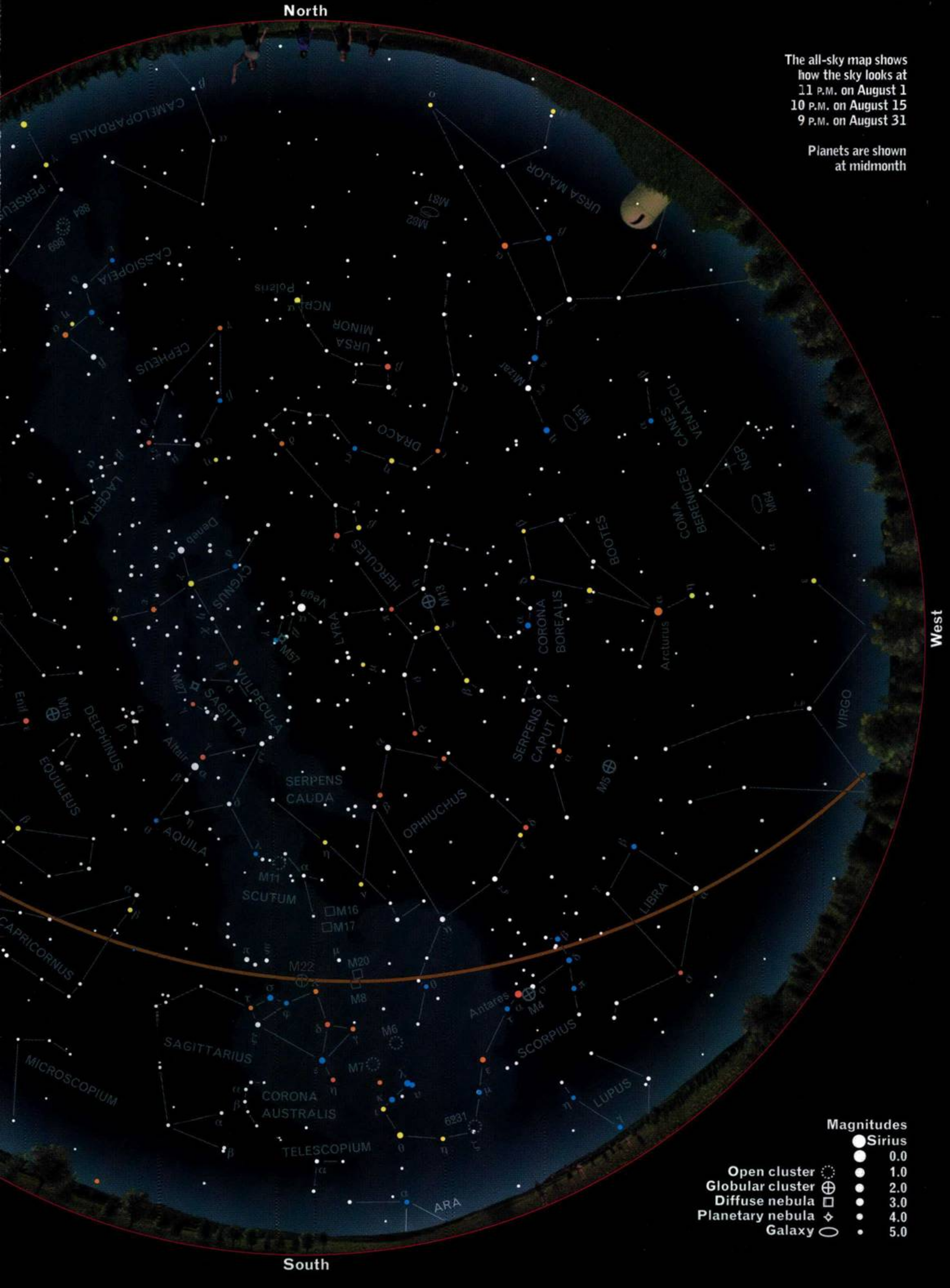
27 Asteroid Iris is at opposition, 7 A.M. EDT (page 61)

30 Last quarter moon is at 10:31 P.M. EDT


SUN. MON. TUE. WED. THUR. FRI. SAT.
1 2 3
4 5 6 7 8 9 10
11 12 13 14 15 16 17
18 19 20 21 22 23 24
25 26 27 28 29 30 31


East
ANDROMEDA
M33
M31
PEGASUS
PISCES
ECLIPTIC
AQUARIUS
URANUS
PISCIS AUSTRINUS

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.



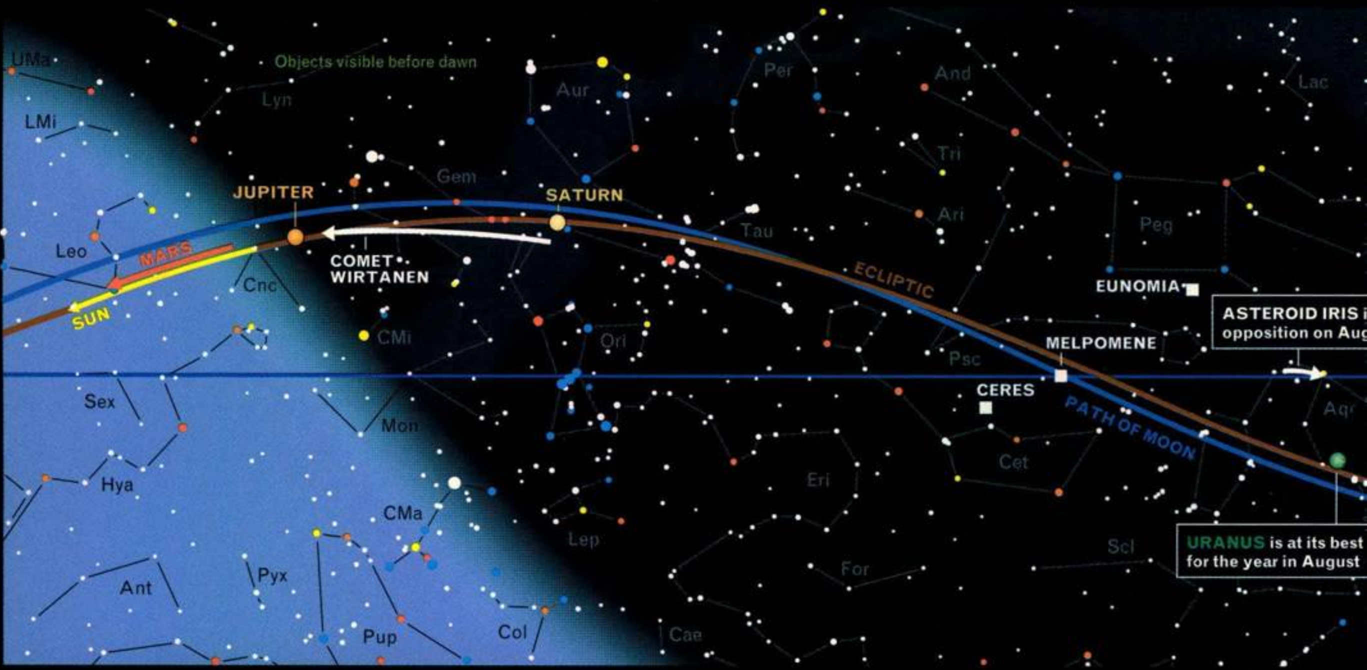
North
South
West
CAMELOPARDALIS
PERSEUS
884
869
CASSIOPEIA
URSA MAJOR
M81
M82
Polaris
URSA MINOR
CEPHEUS
Mizar
M51
DRACO
CANES VENATICI
NGP
COMA BERENICES
M64
LACERTA
Deneb
CYGNUS
HERCULES
BOOTES
Vega
LYRA
M13
CORONA BOREALIS
Arcturus
M57
M27
VULPECULA
SAGITTA
Enif
M15
DELPHINUS
EQUULEUS
Altair
SERPENS CAPUT
VIRGO
M5
SERPENS CAUDA
OPHIUCHUS
AQUILA
M11
SCUTUM
LIBRA
M16
M17
CAPRICORNUS
M22
M20
M8
Antares
M4
SCORPIUS
SAGITTARIUS
M6
M7
MICROSCOPIUM
CORONA AUSTRALIS
LUPUS
6231
TELESCOPIUM
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

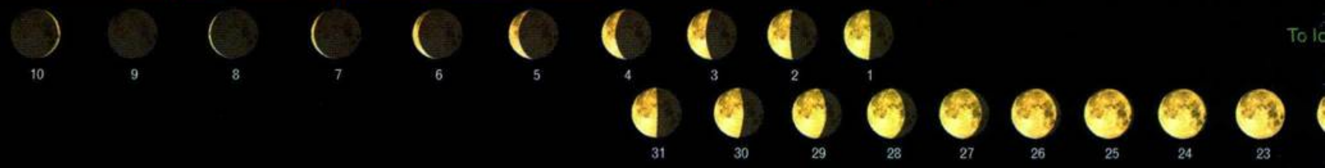
The all-sky map shows
how the sky looks at
11 P.M. on August 1
10 P.M. on August 15
9 P.M. on August 31

Planets are shown
at midmonth

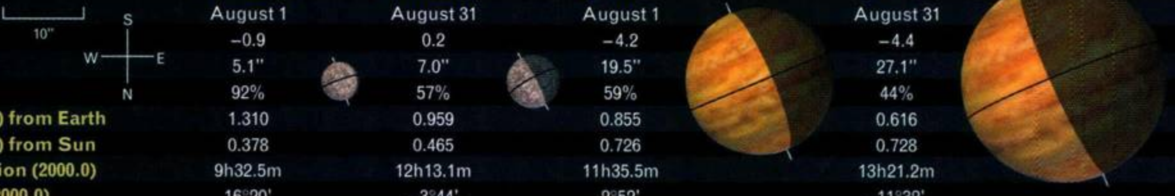
Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system object


Objects visible before dawn
UMa
LMi
Lyn
Aur
Per
And
Lac
Gem
Tri
JUPITER
SATURN
Ari
Leo
MARS
Tau
Peg
COMET WIRTANEN
SUN
Cnc
ECLIPTIC
EUNOMIA
CMi
Ori
ASTEROID IRIS i
opposition on Aug
MELPOMENE
Psc
CERES
Sex
PATH OF MOON
Aq
Mon
Cet
Hya
Eri
CMa
Lep
Scl
URANUS is at its best
for the year in August
Pyx
For
Ant
Pup
Col
Cae

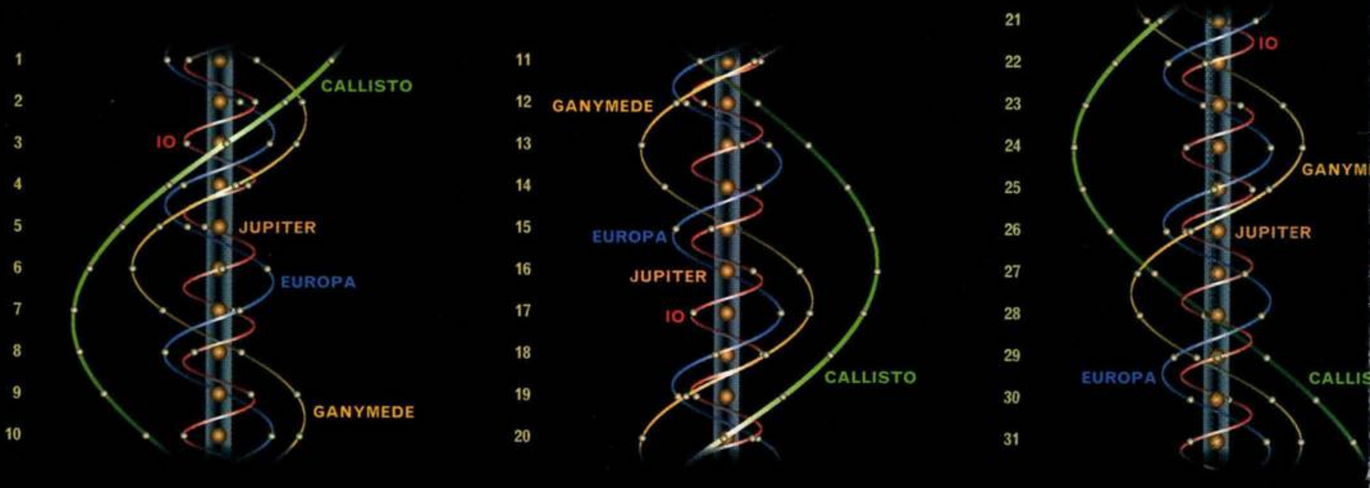

To lo
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27
26
25
24
23

PLANETS	MERCURY	MERCURY	VENUS	VENUS
Date	August 1	August 31	August 1	August 31
Magnitude	−0.9	0.2	−4.2	−4.4
Angular Size	5.1"	7.0"	19.5"	27.1"
Illumination	92%	57%	59%	44%
Distance (AU) from Earth	1.310	0.959	0.855	0.616
Distance (AU) from Sun	0.378	0.465	0.726	0.728
Right Ascension (2000.0)	9h32.5m	12h13.1m	11h35.5m	13h21.2m
Declination (2000.0)	16°20'	−3°44'	2°52'	−11°32'

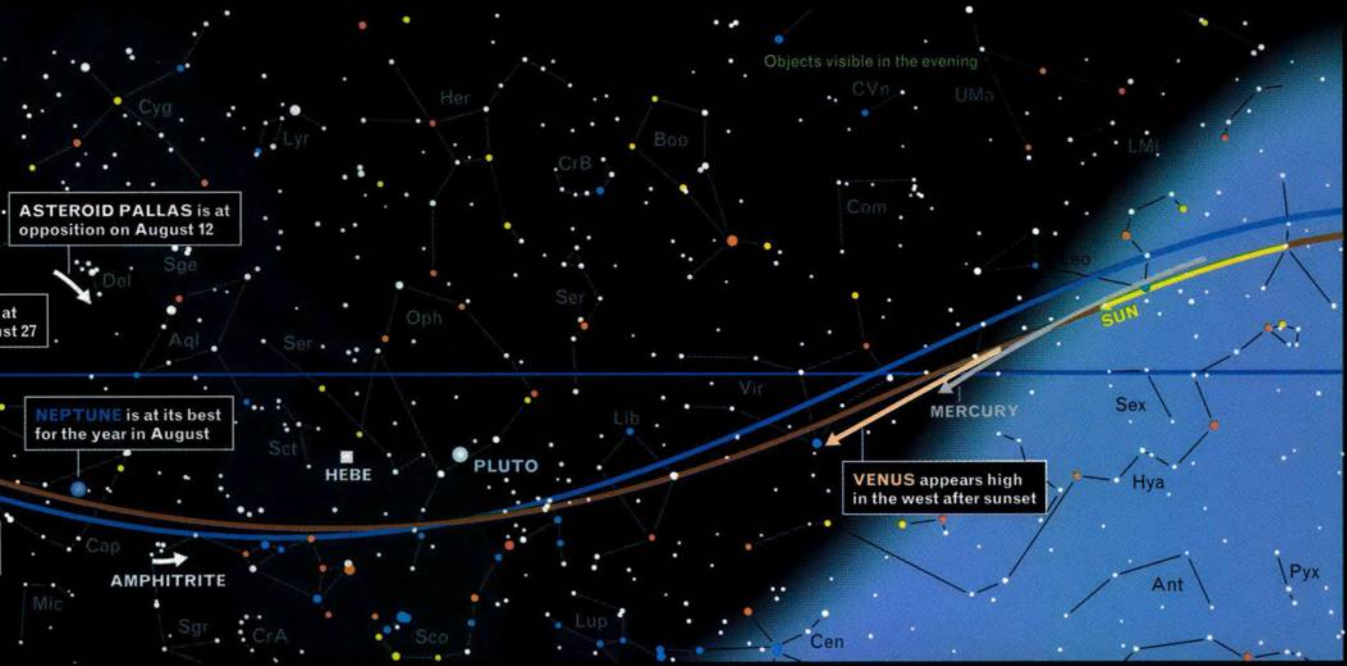


Jupiter's Moons

Dots display positions of Galilean satellites at 6 A.M. EDT on date shown. South is at top to match the view in a telescope.



during the month.


Objects visible in the evening
CVn
UMa
LMi
Cyg
Lyr
Her
Boo
CrB
Com
Leo
SUN
Sge
Del
Aql
Ser
Oph
Ser
MERCURY
Sex
Vir
Lib
Sct
HEBE
PLUTO
Hya
Cap
AMPHITRITE
Ant
Pyx
Mic
Sgr
CrA
Sco
Lup
Cen

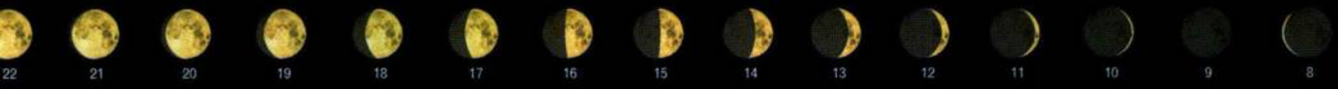
ASTEROID PALLAS is at opposition on August 12

at
ust 27

NEPTUNE is at its best for the year in August

VENUS appears high in the west after sunset

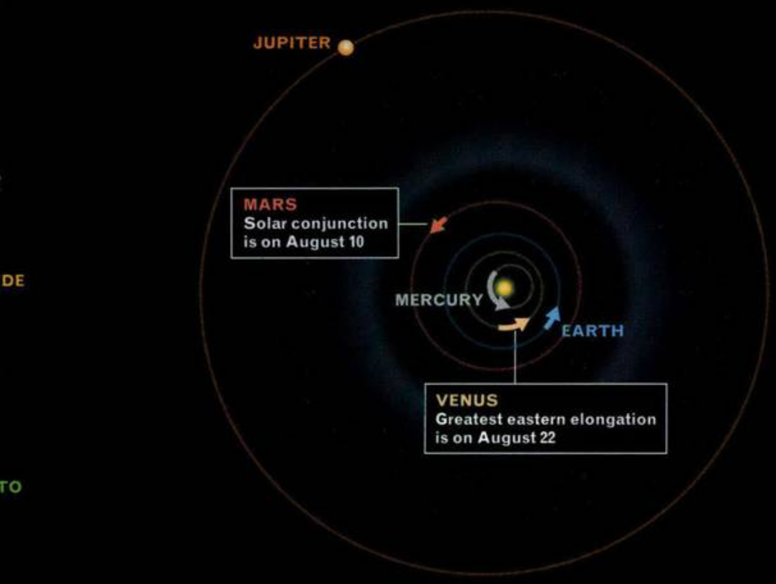
cate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.


22
21
20
19
18
17
16
15
14
13
12
11
10
9
8

IARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
igust 15	August 15	August 15	August 15	August 15	August 15
1.7	–1.8	0.1	5.7	7.8	13.8
3.5"	31.8"	17.4"	3.7"	2.3"	0.1"
100%	100%	100%	100%	100%	100%
2.671	6.200	9.574	18.996	29.100	30.140
1.659	5.254	9.043	20.005	30.089	30.543
h33.8m	8h21.0m	5h43.7m	21h58.0m	20h46.5m	16h58.9m
5°41'	19°52'	22°07'	–13°14'	–17°53'	–12°49'

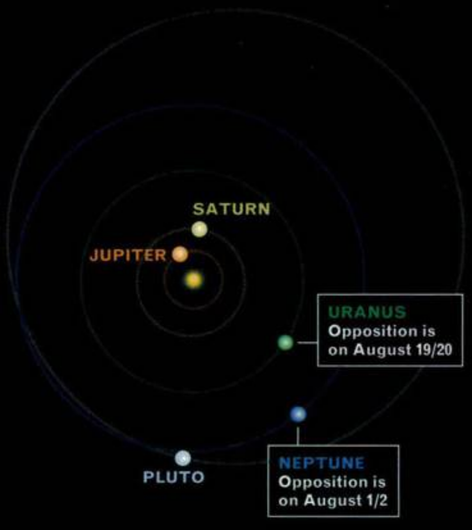
The Planets in Their Orbits

Arrows and dots show planets' positions during the month.


JUPITER
MERCURY
EARTH
DE
TO

MARS
Solar conjunction is on August 10

VENUS
Greatest eastern elongation is on August 22


SATURN
JUPITER
PLUTO

URANUS
Opposition is on August 19/20

NEPTUNE
Opposition is on August 1/2

Prime-time Variety Show — Eta Aquilae

Some observers tend to get hooked on naked-eye variable stars. It's easy to get a kick from walking outside, letting your eyes adjust for two or three minutes, and note, "Hey … Eta is at maximum!" And then observe the star the next night when you might find it obviously paler, followed again by a night when Eta has clearly hit bottom in brightness.

Eta (η) Aquilae is one of the easiest stars to start monitoring. It sits in a memorable pattern just off the eastern (left) wing of the Eagle, near Iota (ι) and Delta (δ) Aquilae. At its brightest, Eta just crests past Delta, while at minimum it's a tad fainter than Iota.

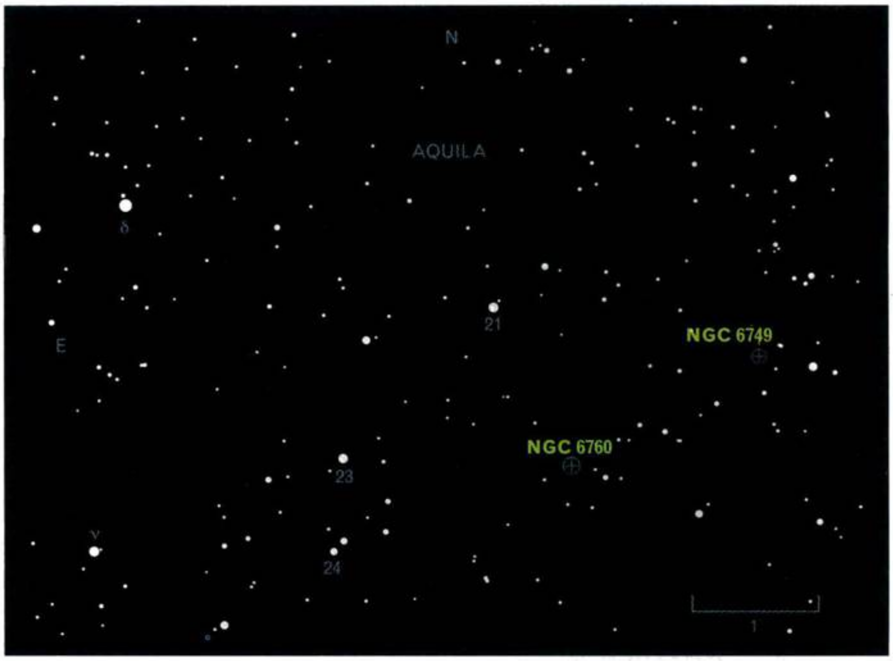
Eta is a member of a special class of variable stars known as Cepheids, which help underpin the distance scale of the universe. Your observations of Eta won't change the Hubble constant, but they may become part of the historic and important data set compiled by the American Association of Variable Star Observers (AAVSO).

Every few days, I submit my estimates across the Internet and then look at how my contributions help fill in the missing gaps in the star's light curve. Check it out at www.aavso.org, click on "Light Curve Generator," and then enter "eta aql" under common name. A few seconds later a graph will pop up.

Globulars in the Galactic Bulge

Globular star clusters continue to provide astronomers with many insights into stellar life cycles and the history of the universe. Summer is the best season for hunting "globs" because we see lots of them. Globulars tend to reside in our galaxy's center, where they're randomly arranged. But because of our solar system's position alongside the galactic center, we earthlings see the globulars as clumped together.

Quite close to the galactic plane (the thin dark zone that you see in edge-on galaxies like NGC 891 in Andromeda) lie two globulars: NGC 6760 and NGC 6749. If you align your finderscope on Delta (δ) Aquilae, you should be able to lock on to a somewhat faint, fuzzy, comet-like object in the field — that's the globular cluster NGC 6749.



NGC 6760 STScI Digital Sky Survey

NGC 6749 STScI Digital Sky Survey

At magnitude 12.4, NGC 6749 is a soft, ill-defined haze only 4' across, and demands good observing conditions to detect it. Only 2° southeast of NGC 6749 lies the much brighter NGC 6760, which glows at 9th magnitude and spans 8'. On a night with superb seeing conditions you'll need a mid-sized scope like a 12.5-incher at modest power to observe even the slightest granulation. These stars are the cluster's brightest at magnitude 15.6.

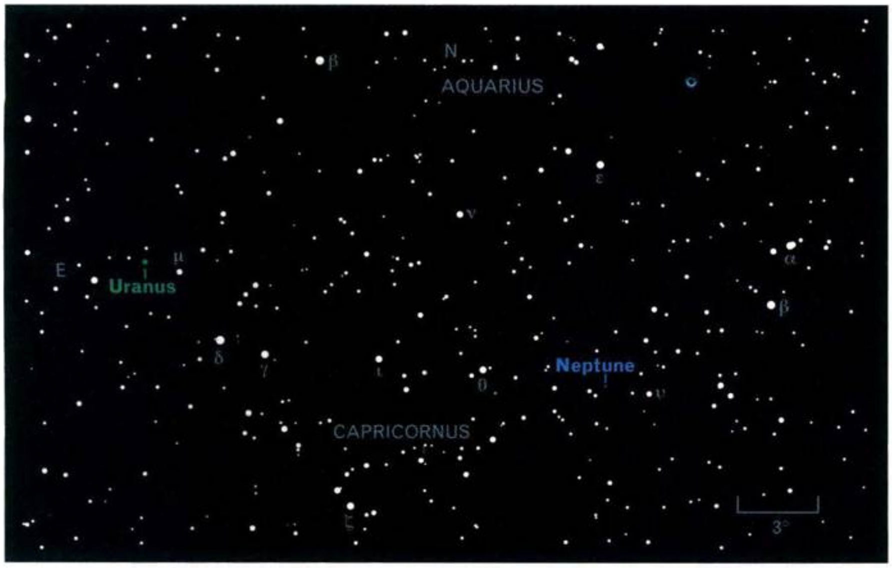
Both of these clusters would look brighter if the dust and gas in the galactic plane did not veil them. Extinction would be complete if such globulars were positioned on the far side of the galaxy. It's hard to visualize it, but these distant objects move in an orbit. Each time their orbital path swings them through the stellar-rich galactic plane, stars get stripped away and further populate the already bulging halo of our Milky Way.

sky Show

Venus punctuates the early evening sky with dazzling brilliance this month. Mercury joins in the performance briefly for observers with a clear western horizon. Later in the evening, binocular observers might have a chance to catch Uranus and Neptune as each planet reaches opposition.

Venus reaches its greatest elongation from the sun on August 22, standing 46° east of our parent star. However, the ecliptic's low inclination to our horizon never places Venus more than 17° high in the sky for observers along the 40th parallel. Venus's apparition is best for Southern Hemisphere observers. Yet the brilliance of the planet still attracts attention around the Northern Hemisphere.

The most photogenic opportunity occurs on August 11, the eve of the great Perseid meteor shower. Soon after sunset on this day, a slender crescent moon hangs delicately above Venus, where less than 5° of sky separate the pair. You can attempt a twilight photograph with your camera set to infinity and fire off a few pictures bracketing exposures around ten seconds in duration. To add beauty to the scene, try placing some foreground trees or buildings in silhouette.

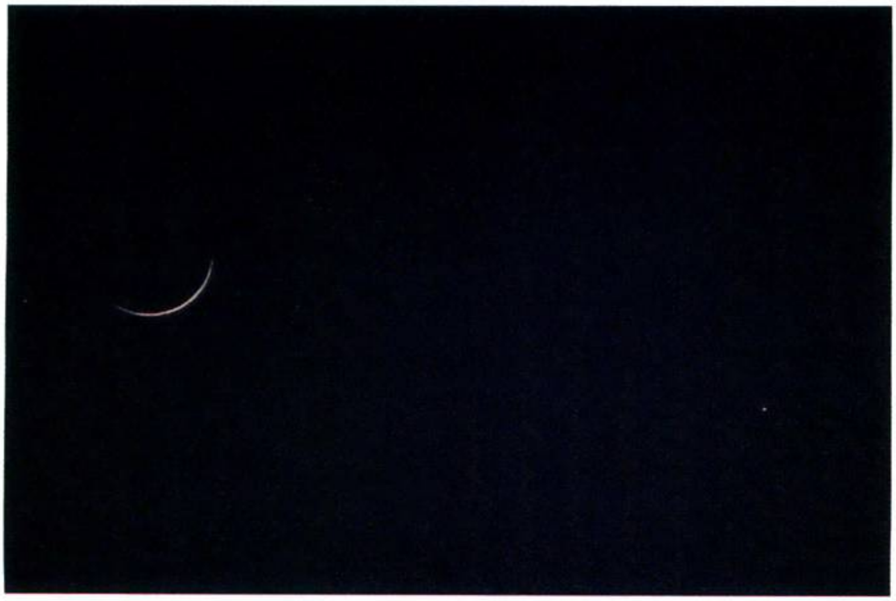


As day turns into night, the bright star Spica in Virgo the Virgin appears to the east of Venus. By month's end, Venus and Spica lie within a 1° circle.

Simple geometry of the solar system shows that on August 22, the day of its eastern elongation, Venus should, theoretically, show a 50-percent phase (called "dichotomy") when viewed from Earth. This would hold true if Venus was both a perfect solid sphere and in a perfectly circular orbit. But Venus's orbit, like all other planets', is slightly elliptical, which causes the moment of dichotomy to occur a few days earlier than August 22. Furthermore, Venus's atmosphere contributes to a premature dichotomy. Careful observations of our sister planet for a few days on either side of August 22 should allow you to determine the moment of its 50-percent phase.

Mercury lies closer to the sun than Venus, and therefore never reaches Venus's degree of elongation. Consequently, Mercury rarely makes an appearance in a dark sky. This month, however, Mercury makes a brief appearance but never stands clear above the horizon. Look for the speedy little planet about 30 minutes after sunset, when it lies far to the right of Venus. Unfortunately, at this time the sky may be too bright to see Regulus standing less than 1° south of Mercury on August 5. On August 9 Mercury lies less than 4° south of the crescent moon. Shining at magnitude –0.4, the planet might just be bright enough before it sets to punch through the twilight sky. But once Mercury dips below magnitude 0 on August 19 it becomes increasingly hard to follow.

Two of the solar system's outer giants, Uranus and Neptune, reach their respective oppositions during August. The moment of opposition is when a planet lies exactly opposite the sun in the sky as viewed from Earth. It's also the time when, by definition, the planet rises at sunset and lies due south in our sky at local midnight. With daylight savings time in effect, local midnight typically occurs close to 1 A.M. local daylight savings time.



A slim crescent moon dwarfs a distant Mercury (off to the right). Robert L. Johnson

Neptune reaches opposition first, on August 2. The planet lies in the upper mid-section of the faint constellation Capricornus the Sea Goat. Using 7x50 binoculars, find the 3rd-magnitude star, Beta (β) Capricorni, and move about 6° southeast to find the lonely magnitude 5.5 star Upsilon (υ) Capricorni. From there, look due east 1.5° to spot Neptune, where it shines at a dim magnitude 7.8. Telescopically, Neptune is rather disappointing through most amateur scopes. You should be able to distinguish Neptune's tiny 2.8" diameter disk from nearby pinpoint stars, and some observers will even detect the planet's subtle bluish hue.

A nearly full moon stands 5° south of Neptune on August 20. The following night it stands 8° southwest of Uranus.

Uranus is an easier target, shining at magnitude 5.8 during its opposition on August 20. It rises an hour later than Neptune. To find Uranus, grab your binoculars and look for the pair of stars Delta (δ) and Gamma (γ) Capricorni, which marks the upper eastern end of the constellation. The planet lies a little over 3° to the northeast of Delta (δ) Capricorni, and lies adjacent to the star Mu (μ) Capricorni, which shines as brightly as Uranus. On August 1 the star and planet lie 1.7° apart. By the end of the month this distance shrinks down to one-half degree when, at first glance, the pair looks like a double star. By mid-September Uranus will share space within the same low-power telescopic field of view as Mu (μ) Capricorni.

Telescope observers should see Uranus reveal its tiny greenish disk as it spans 3.7" at opposition. You won't glimpse any surface details, but tracking the path of this distant wanderer is fascinating. Cast your mind back to 1781 when Sir William Herschel first spotted the greenish intruder. Prior to that date, only five planets were known and all were visible without a telescope. Uranus represented the first telescopic discovery of a planet in our solar system.

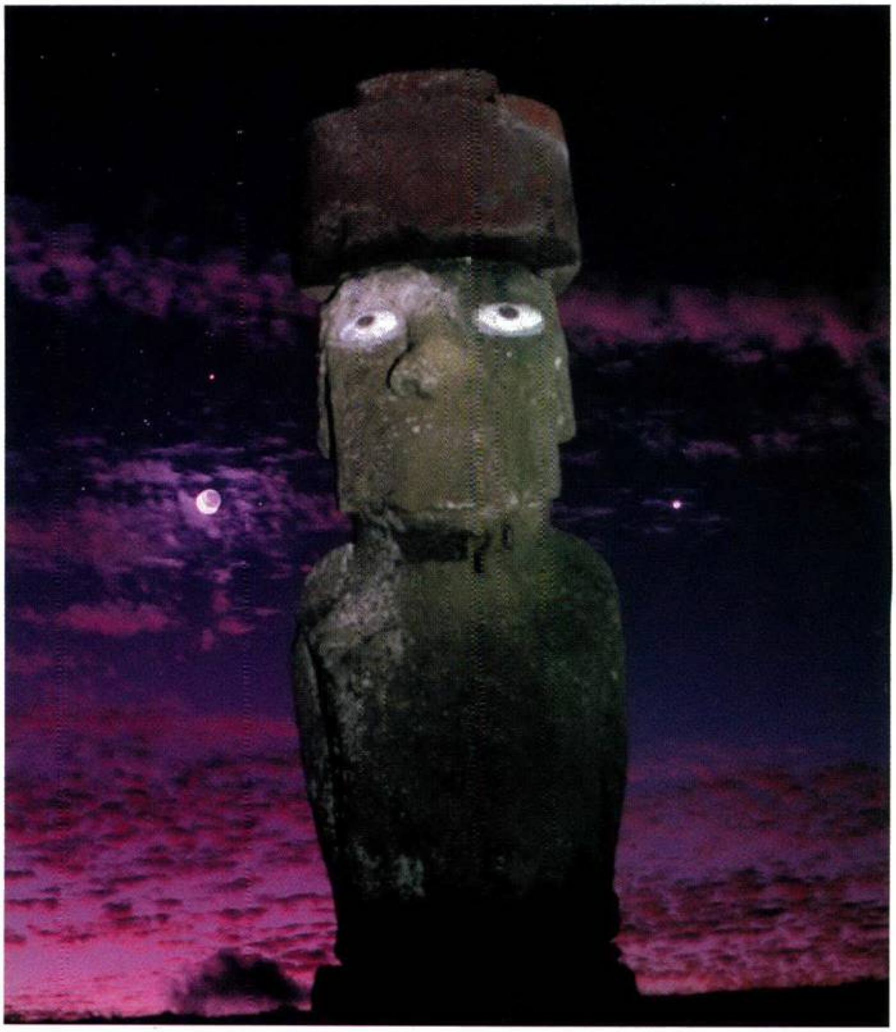
Saturn rises in the early morning hours of August, but by month's end rises within an hour of midnight. A waning crescent moon hops from the west of Saturn to its east between August 4 and 5. The month opens with Saturn lying in the same low-power telescopic field of view as the Crab Nebula and Zeta (ζ) Tauri, the lower horn of the Bull. Throughout August the Ringed Planet moves slowly eastward and ends the month crossing into the northern section of Orion the Hunter, which lies very close to the ecliptic. Saturn shines at magnitude 0.2 and will slowly brighten throughout the rest of the year.

Jupiter rises three hours after Saturn, and lies in the dark morning skies of late August. The huge planet presents a spectacular binocular view since it lies within just a few degrees of the open star cluster Praesepe (M44), also known as the Beehive in Cancer.

Mars is in conjunction with the sun on August 10 and will not be visible for a few months.

Above left: Saturn beckons observers this month. David J. Pontzer

Below: The moon, Venus, and Pollux shine over Ahu Tahai on Easter Island. Olivier R. Staiger

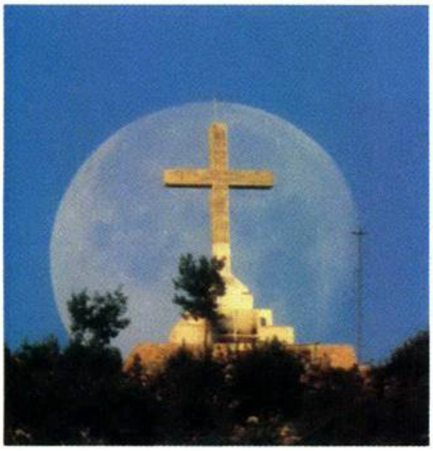


Meteors and Moons

Perseids

The tears of St. Lawrence — another name for the Perseid meteor shower — make their annual descent into Earth's atmosphere this month. The shower began July 17 and continues until August 24, with maximum activity on August 12. The actual peak occurs during daylight in the United States, so the best times to observe will be during the night of August 11 and on into the early morning of August 12. You can almost always catch some post-maximum meteors on the following night.

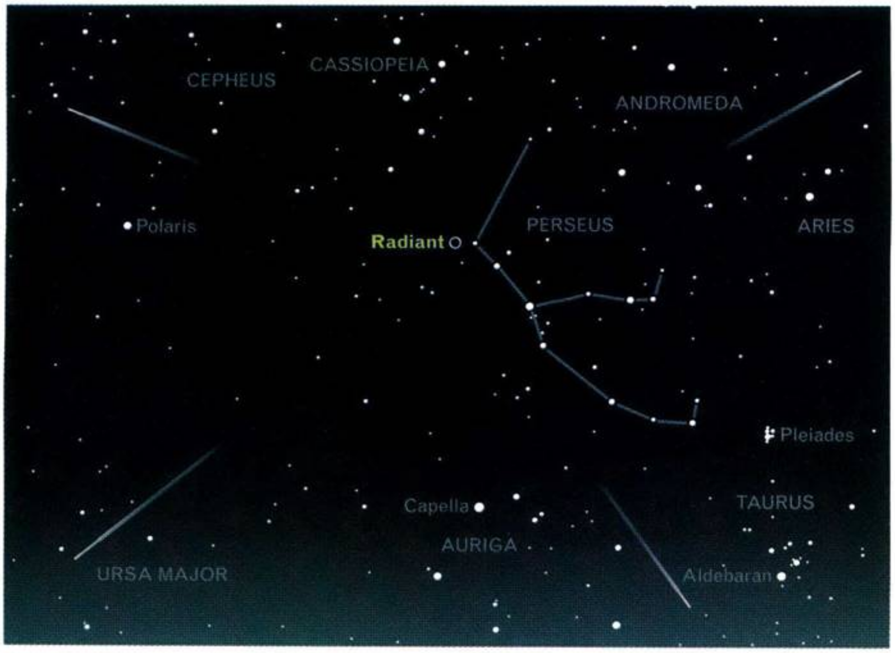
This year's Perseid maximum coincides nicely with a waxing crescent moon, a fine improvement over last year's poor observing conditions. Consequently, when the shower peaks during the early morning hours, dark skies will provide observers with a real treat (weather permitting).



A full moon sets behind Mount Krizevac in Medjugore, (former) Yugoslavia. Larry Landolfi

Although the Perseids of two years ago had unexpectedly low rates; the shower coincided with a most unexpected auroral display, which was even visible from the southern United States. Whilst such auroral events occurring during a meteor shower are extremely rare, the Perseids alone is always a rewarding experience.

The Perseid shower is, in effect, the orbital debris left over the centuries by Comet Swift-Tuttle. The comet was last at perihelion exactly a decade ago, and during the time of its return observers were blessed with increased activity. Rates upwards of 300 meteors per hour were recorded. Today we expect "nominal" rates of around 60-70 per hour during the shower's peak. This translates into any one observer at one location looking in one direction in the sky seeing a meteor about once every minute. Rates depend on the altitude of the radiant, which is the point in space where meteors appear to spring from. The radiant point drifts each night as it lies in northern Perseus — thus the name "Perseid." During the time span of the shower, however, the radiant actually drifts between Perseus and Cassoipeia — a fact few observers are aware of.



Astronomers have recently detected evidence of multiple radiants and more than one main peak in the Perseid shower, so extended observing logs of meteor counts from wide geographical locations are useful. There are a few useful links on the web for reporting observations. One of these is the International Meteor Organization, which you can log on to at the following URL: http://www.imo.net/

Full Moon at Apogee

Like so many other orbital trajectories in our solar system, the moon does not orbit Earth in a circular path. In fact it does so in an elliptical orbit. As a result, its distance from Earth varies. Occasionally throughout the year, the full moon coincides with the time the moon is either closest (perigee) or farthest (apogee) from our planet. August and September represent such a time.

This month the moon reaches apogee just four days after the full moon on August 22. Nominally, the moon's diameter is 30' (a half-degree), but on August 22 it spans a mere 29' 59". This month only two days separate apogee from September 21's full moon. It will appear some 40" smaller than it did during August's time of apogee. Last February the full moon coincided with perigee, and the moon spanned a whopping 33' 28", some 12 percent larger than the full moon at apogee. Of course the apparent size difference is very difficult for the casual observer to notice. So we recommend that you take a picture of the full moon at apogee and then at perigee using exactly the same camera setup. However, this process takes at least six months: The next full moon to coincide with perigee will occur on March 18, 2003. Plan a photograph session during these next two months, and then try to snap a few shots in March so you can perform a comparison. You'll notice an obvious difference in the apparent size of the lunar disk.

Iris Surfs the Water Jar

There are three main reasons why it's a kick to following asteroids: (1) It's neat to see the solar system on the move; (2) it helps give a sense of depth in the sky; and (3) it helps to highlight interesting deep-sky objects, ones that wouldn't normally make it on a list of things to see.

The seventh asteroid discovered, Iris, is reasonably bright at 9th magnitude. This month Iris slides across Aquarius in front of the Water Jar, a Y-shaped group of modestly bright naked-eye stars. Smack in the middle of the Y is a lovely binary star Zeta (ζ) Aquarii. If you push a 60mm refractor to its maximum power of 120x, you should see the two components, like slightly unequal headlights in the distance.

If you can spot Zeta on the night of August 1 or 2, then Iris is the closest star-like object to the north, only 9' away — less than one-third the apparent diameter of the moon. On the night of August 11 Iris practically runs over a 9th-magnitude star. It's like watching a binary star separate in real time.

Comet Wirtanen Leads the Dawn

Thank our lucky comets these last couple of years. From LINEAR A2 to Ikeya-Zhang, short notice comets have delivered the best views of the bunch.

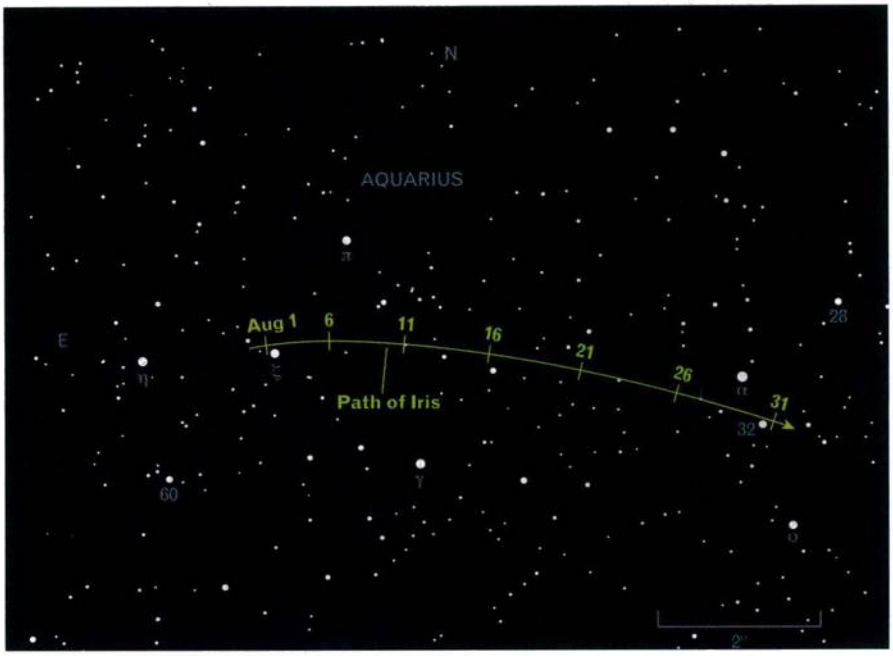
With the exception of big objects like Hale-Bopp, and hopefully comet NEAT in May 2004, the only reliable comet warnings we can make are for periodic comets, those with orbits shorter than 200 years or so. The brightest of the periodic comets this August should be 46P Wirtanen. The 46 means that it was the 46th comet recognized as returning.

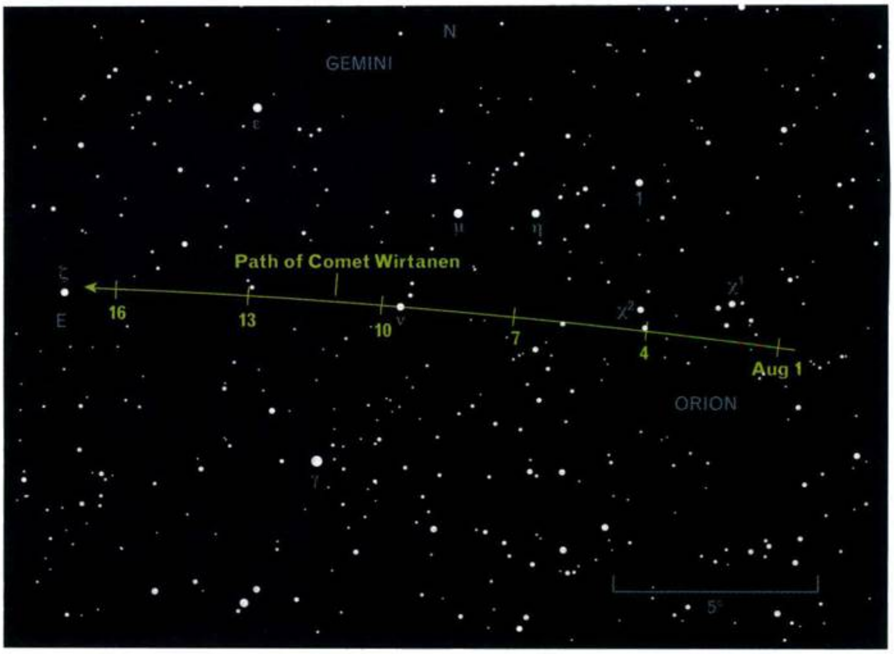
Wirtanen orbits the sun in roughly 5.4 years. But it will be a couple of decades before we get a good look at it from the Northern Hemisphere. However, if things go according to plan, we'll visit this comet with an interplanetary probe in 10 years or so.

Unless comet Wirtanen undergoes an outburst, the dirty snowball should glow at a fuzzy 10th to 11th magnitude, just beyond the range of standard binoculars from a dark observing site. This range in magnitude corresponds to brightness on the fainter end of the Messier deep-sky list. So the best time to see Wirtanen is just as dawn breaks, perhaps at the end of a great night's observing at a star party on the weekend of August 10.

Wirtanen will soar just inside the body of Gemini, to the lower left of Nu (ν) Gem. Since there are no galaxies or nebulae near this position, you shouldn't confuse the comet with a deep-sky object. Have a look at Wirtanen before you set your eyes on Saturn; otherwise the ringed wonder just might fry your dark adaptation. ■

Martin Ratcliffe is President of the International Planetarium Society and observes from Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.





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About Your Professor:

MICHAEL STARBIRD (Ph.D., University of Wisconsin, Madison, 1974) is a Professor of Mathematics and a University Distinguished Teaching Professor at The University of Texas at Austin. He has also served as a Member of the Technical Staff at the Jet Propulsion Laboratory. He is deeply interested in bringing the intrigue and fascination of mathematics to those who are not necessarily mathematically oriented. The *American Mathematical Monthly* acclaimed his recent book, *The Heart of Mathematics: An Invitation To Effective Thinking*, co-authored with Edward B. Burger, as possibly the best math book—textbook or not—for non-mathematicians it had ever reviewed.

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Back to Basics With Binoculars

When it comes to viewing the heavens, two eyes are definitely better than one.

by Phil Harrington

For amateur astronomers of any skill level, binoculars provide a fresh perspective of the cosmos. There's something about looking skyward and taking in the big picture, something about wistfully scanning the heavens with binoculars that we cannot achieve with a telescope. A binocular's low power and wide fields of view make for ideal casual and sophisticated observing programs. So regardless of your experience level as an amateur astronomer, you should always keep binoculars at your side whenever you are observing.

Our powers of resolution, color perception, and detection of image contrast improve dramatically when using both eyes. As proof, test this out on the next clear, moonless night: With both eyes open, cover one with your hand and look at the sky. Pick out a specific area and make a mental note of the faintest stars that are visible. Now uncover your second eye and look at the same area. You should see more stars. In fact, you may experience a 10 percent improvement in perception using both eyes.

This good news gets even better when viewing a nebulous object, such as the Milky Way's hazy band of light. Some observers enjoy up to a 40 percent increase in contrast perception of hazy objects simply by using both eyes. Using the Milky Way as your target, alternately cover and uncover one eye as before. The contrast between the soft glow of our galaxy's star clouds and the background sky appears much more distinct through both eyes than when using only one. And while these two tests were conducted without optical aid, expect similar results between binoculars versus an equivalent aperture monocular or telescope.

To understand why two eyes are better than one for observing, let's examine how the human eye works. Light enters the eye through the lens, which focuses the image onto the retina. The retina converts the focused image into electrical pulses and sends them to the brain, which interprets the pulses into the image that we sense. When we rely on only one set of pulses (as when using one eye), any inconsistencies in the signal interfere with the final image. But with two sets of signals to interpret, the brain works to average the electrical messages, thus resolving the fainter, lower contrast objects in finer detail.

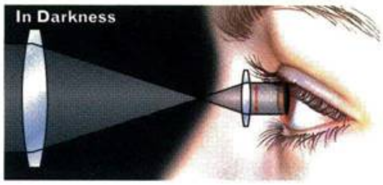
All photos: *Astronomy* Magazine

+ 0 −

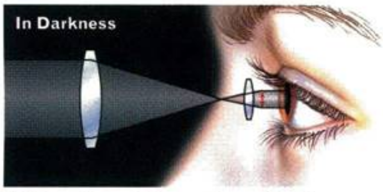
Binoculars are usually referred to by two numbers separated by an "x," such as 7x35 (pronounced "7 by 35"), 10x50, and so on. The first number is the binoculars' power, or magnification of the view. The second number refers to aperture — the diameter of the binoculars' front (objective) lenses — in millimeters. Selecting the right combination of aperture and magnification is critical. Seven- to 10-power binoculars (that is, 7x to 10x) work great for wide-field views of the Milky Way, while observers often prefer higher-power glasses (10x and above) for close-up views of deep-sky objects or the moon.

Remember that in terms of aperture, big is not always best. The weight of binoculars increases dramtically with aperture size. This is especially important if you plan to hand-hold the binoculars. Most people support 50mm binoculars with minimal strain and fatigue. Beyond that size, the extra weight usually makes hand support impractical.

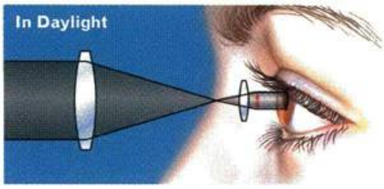
Exit Pupil



Pupils dilate to 7mm at night, so choose binoculars that give an exit pupil that big.



If the exit pupil is much smaller than 7mm, the image will appear dark.



Pupils contract to 3mm in daylight, so binocs with a small exit pupil work fine.

Knowing Your Pupils

Big may not be better for other reasons as well. For the best night vision, the diameter of the beam of light — called the exit pupil diameter — that leaves the binoculars's eyepieces must pretty much match our own pupil's diameter. Generally, the pupil contracts to about 2.5mm (0.1 inch) in bright daylight and expands, or dilates, to about 7mm (0.25 inch) in total darkness.

The amount of dilation for your pupil depends on both your age as well as the observing conditions. If you're about 30 years old or younger and spend most of your observing time under dark, rural skies, your pupils probably dilate to about 7mm. This means that you should look for a pair of binoculars with a 7mm exit pupil, such as 7x50, 10x70, or 11x80.

But if your location suffers from light pollution, or you are over the age of 30, then your pupils may never dilate beyond 5mm or 6mm. Urban and suburban observers will likely do better by selecting smaller exit-pupil binoculars as well, such as 7x35s or 10x50s. Calculate how large the exit pupil is for a particular pair of binoculars by dividing the objective's diameter by the power. For instance, a 7x50 pair of binoculars has a 7.1mm exit pupil, while 10x50s have a 5mm exit pupil.

"True" Images

Telescopes almost always show images that are either upside-down, flipped left-to-right, or both. This makes little difference, because there is no up and down in space — everything is up. Since binoculars are primarily used for terrestrial viewing, however, their images must be more true.

All modern binoculars use a series of internal prisms to flip the view right side-up. Two styles of prism assemblies are used in binoculars: roof prisms and Porro prisms. Roof-prism binoculars have sleek, straight barrels. They are great for watching a ball game or at the opera, but most are not ideally suited for astronomical use.

The disadvantage to this style is that one internal surface must be aluminized in order to bounce light through the binoculars. As the light strikes the aluminized surface, a bit of it is lost, which dims images. A second disadvantage to roof-prism glasses is their higher cost, which is caused in part by the precision required for their assembly. Unless constructed with great care, the image quality of roof-prism binoculars is poor for astronomical viewing.

The more common binocular design uses Porro prisms, which are immediately recognizable by their familiar zigzag barrels. When constructed of a high-quality glass, Porro prisms have "total internal reflection," which means that light passes through and exits the prism assembly without the need for an aluminized surface. The net result is brighter images — an important consideration for astronomical viewing.

Porro prisms are usually made from either borosilicate (called BK–7) or barium crown (called BaK–4) glass. The latter, usually reserved for more expensive binoculars, gives brighter, sharper images than BK–7 prisms. If you happen to already own a pair of binoculars with BK–7 prisms, don't despair. While BaK–4 prisms are better, I continue to enjoy using my 30-year-old, 7x50 binoculars with BK–7 prisms.

Most manufacturers engrave "BaK–4 prisms" right on the binoculars, but you can also check this yourself. Hold the binoculars at arm's length and look at the circle of light "floating" behind each eyepiece. BaK–4 prisms produce clear circles, while BK–7 prisms show a diamond-shaped exit pupil.

Buying Binoculars

If you're in the market for a first pair or if you are thinking of upgrading the binoculars that you currently own, consider price, optics, optical coatings, and portability. These most affect outcome.

Holding binoculars steady for more than a few minutes is a surefire way to induce arm strain and brings a quick end to a night's observing. A tripod makes binocular viewing much easier.

As far as price goes, you pretty much get what you pay for with binoculars. A pair of 7x50 binoculars priced at $50 will not produce the same quality image as 7x50 binoculars that cost $500. The quality of the optics — the lenses and prisms — sets them apart.

Optical coatings improve light transmission and reduce scattering. An uncoated lens reflects about four percent of the light hitting it. By applying a thin layer of magnesium fluoride onto both surfaces of the lens, reflection is reduced to 1.5 percent. A lens coated with magnesium fluoride exhibits a purplish tint when held at a narrow angle toward a light.

Uncoated lenses have a whitish glint. Top-of-the-line binoculars receive multiple anti-reflection coatings, reducing reflection to less than 0.5 percent. Most multi-coated lenses show a greenish reflection when turned toward a light. Be sure to insist on fully coated, or better yet, fully multi-coated, optics; otherwise, some internal lens surfaces probably won't be coated.

No Assembly Required

While some telescopes require a half hour or more to set up, it's quite simple to pull binoculars out of the case and begin scanning the heavens. But observers soon realize that holding binoculars steady for an extended time becomes difficult.

While most of us have little trouble supporting 7x50 glasses for short periods while viewing terrestrial objects, such as sailboats on the horizon, we quickly grow fatigued pointing binoculars skyward while searching for a faint celestial object near the zenith. Larger binoculars present an even greater burden. As aperture climbs, so will weight and size. Quivering binoculars are useless.

To steady any size binoculars, try this trick. Instead of holding them around the prism end (eyepiece end) of the barrel, which places the entire weight of the objective lenses out in front, shift your grip to the objective (front) end of the barrels. This directly supports the overhanging weight, greatly reducing shake. Even so, extended viewing causes fatigue, making some sort of mechanical binocular support necessary. Many people attempt to use camera tripods for this problem, but they quickly find that most are not suitable for astronomical viewing.

The flimsy legs and weak heads of less expensive tripods prove little better than hand-holding binoculars. A good tripod has cross-braced telescoping legs that lock firmly in place. Since most of your viewing time will be spent looking up from under the binoculars, the tripod's maximum height is also an important consideration.

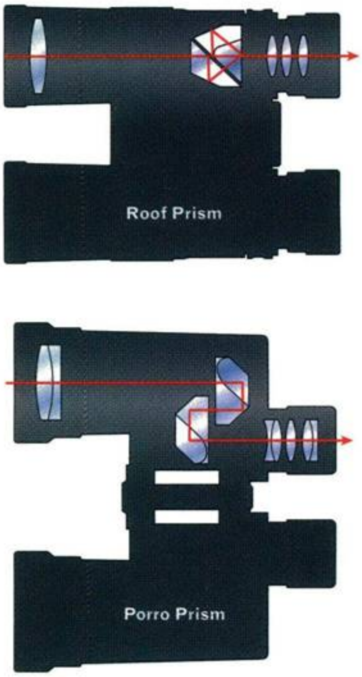
Nothing takes the joy out of stargazing quicker than having to bend and strain just to look through the eyepieces. Depending on your height, the tripod should raise the binoculars six feet or more. Anything less and you will feel as if you are doing the limbo whenever you gaze skyward.

Seeking a Steady Mount

Several companies, including Universal Astronomics, T & T Binocular Mounts, Virgo Astronomics, Blaho Company, and Orion Telescopes, sell binocular mounting systems that hold binoculars steady regardless of their viewing angle. These "flexible-parallelogram" mounts, fashioned after a folding-arm desk lamp, raise the binoculars to eye level while extending them away from the legs of the supporting tripods. A review of binocular mounts ran in the September 2000 issue of *Astronomy* and is available at www.astronomy.com.

But whether you own a top-of-the-line binocular model or an inexpensive one picked up at a department store, the best binoculars are those that are used and enjoyed most often. There is no such thing as bad binoculars for astronomy, since all will show more of the universe than our eyes alone. Their two-eyed view, portability, affordability, and ease of operation make binoculars a favorite way of touring the universe. ■

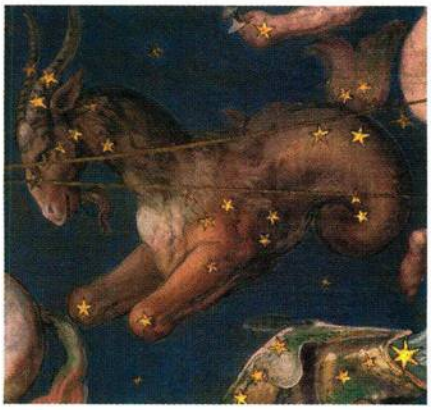
Binocular Types



Roof-prism binoculars may be compact, but porro-prism models usually cost less and provide sharper, brighter images.

Phil Harrington always keeps binoculars handy during observing sessions. Visit his website at www.philharrington.net.

Capricornus, Microscopium, and Corona Australis



Don't miss these Southern Hemisphere constellations, guaranteed to bring observers many deep-sky delights.

by Tom Polakis

The stretch of sky trailing behind Sagittarius is easy to overlook. Very distant galaxies in sparse starfields take the place of brilliant clusters and nebulae. But if you're willing to probe a little deeper, the autumn sky will no doubt reward you with its hidden cosmic treasures.

Capricornus the Sea Goat is a recognizable grouping of a dozen or so naked-eye stars, five of which are brighter than 4th magnitude. In the northwest corner of the constellation is Alpha (α) Capricorni, a wide pair showing its separation even with unaided vision. Alpha^{2} Capricorni is a magnitude-3.6 star of Spectral Type G6 that lies 100 light-years away, while its partner, Alpha^{1} Capricorni, is a half magnitude fainter and six times farther away. On the east end of Capricornus is its brightest star, Delta (δ) Capricorni, a 3rd-magnitude gem only 40 light-years away. To the south of Capricornus is Microscopium — the Microscope — a small and indistinct group of 5th-magnitude stars.

This month, we also sweep the region below Sagittarius to find Corona Australis, the Southern Crown. Its faint stars form a prominent "C" shape similar to its northern counterpart. Its brightest member is 4th-magnitude Beta (β) Coronae Australis, whose Spectral Type K0 is revealed to the naked eye by its yellowish hue.

We begin in Corona Australis with the bright globular cluster **NGC 6541**, which is best found by hopping from the stinger stars of Scorpius. Seen from only 24,000 light-years, NGC 6541's brightest stars are magnitude 12, easily resolved in a 6-inch telescope from a dark site. This cluster is less than 20° from the galactic center, and is situated among field stars that rival those in Sagittarius. An 8-inch scope reveals hundreds of stars radiating from a sharply defined core.

The real action in Corona Australis is near the stars that form the crown on the east edge of the constellation. Just 1.5° east of Beta Coronae Australis is the bright planetary nebula **IC 1297**. This highly excited nebula is similar in structure to NGC 7662, the Blue Snowball, in Andromeda. A 22"-diameter disk surrounds an inner ring 13" across. Backyard telescopes reveal only the inner ring, which glimmers in an 8-inch scope. Use a nebula filter to locate the small planetary, and then step up in magnification, removing the filter. A bluish hue to the sharp-edged disk is apparent using direct vision. A large telescope may turn up the 14th-magnitude central star.

The region between Epsilon (ϵ) and Gamma (γ) Coronae Australis packs a wide range of Milky Way objects into a single telescopic field. Begin with **BSO 14**, a double star catalogued by Brisbane Observatory. This is an almost perfectly matched pair of bluish stars that resolve well at magnifications above 20x. Look closely with a 10-inch or larger scope for the faint haze of the surrounding emission nebula IC 4812. Notice that the starfield is rich to the west and pales dramatically to the east.

From this pretty double star, look 12' to the north-northeast for the bright reflection nebula **NGC 6726**. About 3' across, bright stars enhance this nebula along its northeast and southwest edges. The northeastern star is TY Coronae Australis, a variable star of 9th- to 13th-magnitude range. The distinct, cometary form of the reflection nebula **NGC 6729** lies only 4' to the southeast. Observers who have noted a similarity to Hubble's

Artwork from *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

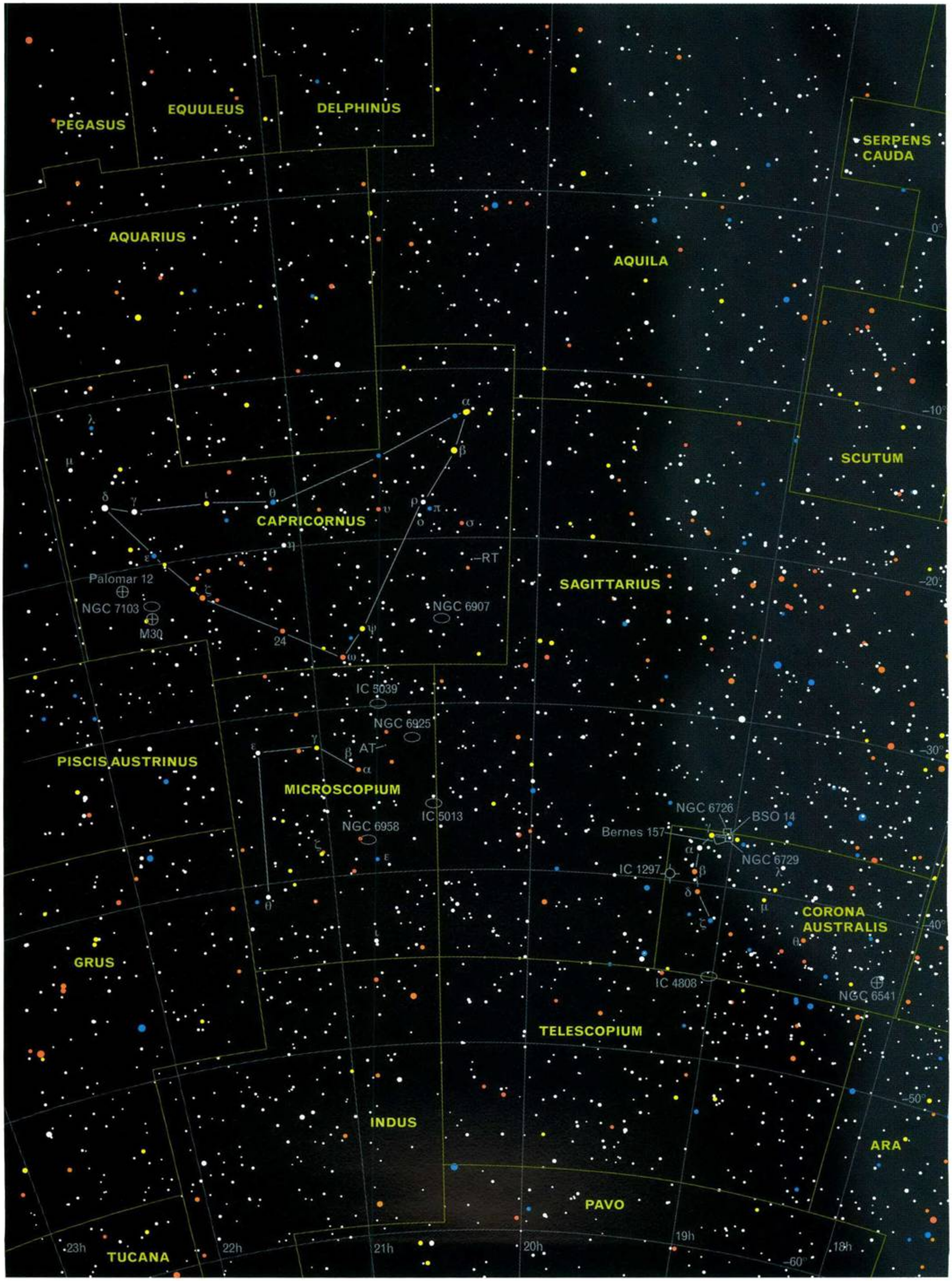
M30

Preston Scott Justis

Variable Nebula are right on the mark. Like its brighter cousin to the north, NGC 6729 is a variable nebula illuminated by a star at the "head" of the fan. Variations in form and brightness are created by the projection of shadows from material near the star. Edwin Hubble noted these variations in NGC 6729 as early as 1921. In a medium-sized scope, the reflection nebula is a wisp extending away from the 11th-magnitude R Coronae Australis. NGC 6729 better resembles a comet than Hubble's Variable Nebula, as it is much thinner — five times as long as it is wide.

Look about 1° to the southeast of these nebulae to find the very opaque dark nebula **Bernes 157**. Visual absorption of starlight in this region is as high as eight magnitudes, so you can see only a handful of stars. Like most prominent dark nebulae, Bernes 157's three-dimensional nature manifests itself in the form of a hazy edge where the starfield slowly returns to form.

In Capricornus, begin with a double star located in a small triangle 3° south-



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NGC 6907
IC 5039
NGC 6925
AT
PISCIS AUSTRINUS
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MICROSCOPIUM
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NGC 6958
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IC 5013
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−30°
NGC 6726
BSO 14
Bernes 157
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α
NGC 6729
IC 1297
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CORONA AUSTRALIS
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−40°
GRUS
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IC 4808
NGC 6541
TELESCOPIUM
−50°
INDUS
ARA
PAVO
23h
TUCANA
22h
21h
20h
19h
−60°
18h

southeast of β Capricorni. **Omicron** (o) **Capricorni** is a pair of white stars whose split resolves easily in even the smallest of telescopes. Like most wide doubles, this is a chance alignment — the two stars are actually separated by 100 light-years.

If you move your sights 4° southwest, you'll land on a beautiful carbon star glowing in its characteristic red hue. **RT Capricorni** varies irregularly between 7th and 11th magnitude but its light curve is poorly defined. Visual magnitude estimates of red stars are notoriously unreliable due to the Purkinje effect, in which red objects appear brighter if stared at for a prolonged period. Surprisingly, RT Capricorni often appears the reddest when at minimum brightness.

In the southwest corner of Capricornus is a galaxy that appears as a one-armed spiral in backyard scopes. **NGC 6907** exhibits barred spiral structure in a 10-inch telescope at a dark site. The bar is oriented east-west, and a plainly visible arm — highlighted by two large stellar associations — curves to the north from its east end. Interestingly, it appears as though there is no corresponding arm jutting from the west end of the bar. But a look at long-exposure photographs reveals that such an arm indeed exists, but isn't advertised by bright stellar associations. NGC 6907 also shows "bar within a bar" structure. Large telescopes should allow you to see a small bar structure near the galactic core, oriented with a 45° pitch.

Martin Germano

Now if you pan south into Microscopium you'll find a distant galactic duo — **IC 5039** and **IC 5041** — involved in a gravitational dance. IC 5039 is a spiral galaxy paired with the barred spiral IC 5041 galaxy just 10' to the north-northeast. Both are a telescopic challenge: The former appears as a dim 1.5' by 1' haze with a broadly concentrated center, and the latter appears slightly smaller with a sharper central concentration. Though the two galaxies are separated in space by 400,000 light-years, or several times the distance between the Milky Way and the Magellanic Clouds, they still exert gravitational influence on each other.

If you travel 3° to the southwest of the dancing partners, you'll find **NGC 6925**, the humble showpiece of Microscopium. Telescopically, NGC 6925 appears 3' by 1' and is oriented east-west. Its faint stellar nucleus glows dimly amidst an otherwise bright core region. Viewing the galaxy at high magnification might reveal a hint of its delicate spiral structure.

A challenging binary star with faint components lies less than 1° away. **AT Microscopii** is the slightly fainter member of this gravitationally bound pair with a 675-year period of revolution. The secondary star lies 3.6" due north of the primary. To cleanly split the stars, try using magnifications in excess of 200x. AT Microscopii is a classic flare star; as a Spectral Type M star it radiates most of its energy in red light, but will

Deep-Sky Objects in Capricornus, Microscopium, and Corona Australis

Object	R. A. (2000.0)	Dec.	Mag.	Size/Sep.	Type	Notes
NGC 6541	18h08.0m	–43°42'	6.1	13.1'	GC	
IC 4808	19h01.1m	–45°19'	12.9	1.9' x 0.8'	Gal	SA(s)c
BSO 14	19h01.1m	–37°04'	6.6/6.8	13"	Dbl	
NGC 6726	19h01.7m	–36°53'	—	9' x 7'	BN	
NGC 6729	19h01.9m	–36°57'	—	1' x 1'	BN	
Bernes 157	19h02.9m	–37°08'	—	55' x 18'	DN	
IC 1297	19h17.4m	–39°37'	10.7	7"	PN	
RT Capricorni	20h17.2m	–21°20'	7	—	Star	Carbon star
NGC 6907	20h25.1m	–24°49'	11.1	3.2' x 2.3'	Gal	SB(s)bc
IC 5013	20h28.6m	–36°02'	11.7	1.8' x 0.6'	Gal	SB(s)0
Omicron Capricorni	20h29.9m	–18°35'	5.9/6.7	22"	Dbl	
NGC 6925	20h34.3m	–31°59'	11.3	4.7' x 1.3'	Gal	SA(s)bc
AT Microscopii	20h41.9m	–32°26'	10.5/10.8	3"	Dbl	
IC 5039	20h43.2m	–29°51'	12.6	2.3' x 0.7'	Gal	Sbc
NGC 6958	20h48.7m	–38°00'	11.3	2.5' x 2.1'	Gal	E+
NGC 7103	21h39.9m	–22°28'	12.6	1.4' x 1.2'	Gal	E+1
M30 (NGC 7099)	21h40.4m	–23°11'	7.3	11'	GC	
Pal 12	21h46.6m	–21°15'	11.7	2.9'	GC	

Object: Designation in NGC or other catalog. **R. A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep.:** Size in arcminutes or arcseconds; separation in arcseconds. **Notes:** Hubble type for galaxies.

The Sea Goat

I am the long world's gentleman, he said, And share
my bed with Capricorn and Cancer.
Altarwise by Owl-Light, *Dylan Thomas (1914-1953)*

Almost by its very nature the Sea Goat is a manifestation of opposites. A water-loving fish and a land-loving goat conjoined at the midsection. Also, this heavenly hybrid creature was revered by ancients in the Southern Hemisphere as the high celestial home of the sun during the summer solstice. Meanwhile, for denizens of the Northern Hemisphere the star grouping framed the low-lying sun during the relatively dark, cold days around the winter solstice.

A few millennia before Christ the sun rose to its highest declination in the constellation Cancer and sunk to its lowest in Capricornus. Because of this, many civilizations in the Northern Hemisphere regarded Cancer as the northern gate of the sun and Capricornus as the southern.

Porphyry's "In the Cave of the Nymphs," an essay written in roughly 300 B.C., depicted souls as entering the heavenly gates of Cancer before dropping down to their incarnation on Earth. Then, after virtuous earthly lives these souls would pass through the gates of Capricornus to reenter heaven.

The Sea Goat derives from the Mesopotamian god known as Ea, the ideogram of which means the abode of the waters. This deity was invoked as the Spirit of the Land and Water Surface who had as his permanent address the abyss — helping to explain his manifestation as god-fish, soon known as fish-man or fish-goat. Ea would occasionally emerge from the depths of the ocean in order to instruct men, only to disappear from mortal sight at night.

Capricornus soon became Ea's symbol, a representation of his land-water ambivalence. And he was lord of the sign of Capricornus as Sumerian astronomers drew the constellation-filled maps of the sky as we know it today.

unpredictably brighten by many magnitudes in blue light for a short time.

IC 5013 is the brighter member of an isolated pair of faint spiral galaxies that lie 115 million light-years from Earth. The two galaxies — which themselves are separated by roughly 20,000 light-years — appear to overlap in the eyepiece. IC 5013 is only 1' long and half as wide, and looks like an edge-on spiral galaxy. Just west of its south end, IC 5011 is a diminutive circular smudge 30" across, barely visible in a 13-inch telescope.

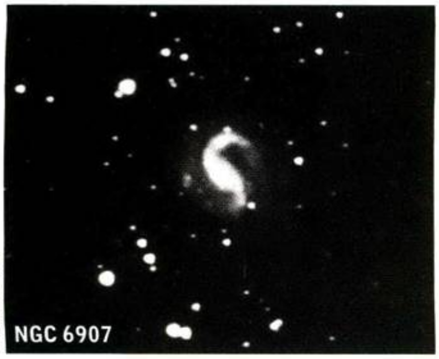
Drop 4° south of Alpha Microscopii and you'll find the large elliptical galaxy **NGC 6958.** It's faint, circular, and measures about 2' across, and it shows a weakly concentrated center. NGC 6958 forms the vertex of an isosceles triangle with two 10th-magnitude stars several arcminutes to the west.

Returning to Capricornus, you'll find the sole Messier object of the tour. **M30** (NGC 7099) is a bright globular just beyond the reach of naked-eye visibility. With stars as bright as 12th magnitude, it resolves to the core in a 6-inch scope. M30 is an example of a core-collapse cluster, exhibiting extremely high stellar density at the center. A 12-inch telescope shows a swarm of hundreds of stars reaching out to a diameter of 8' with a broadly concentrated center. Just off the west edge lies a 9th-magnitude star.

A group of galaxies lies less than 1° north; **NGC 7103** is the brightest member. All of these galaxies lie in a chain to the north of NGC 7103, and are a challenge to see under even the best observing conditions with a 16-inch scope. Even NGC 7103 is quite faint, revealing no more than a 1' haze with a lightly concentrated core. Save this galaxy for the best nights, and see if you can pick off any of its fainter companions.

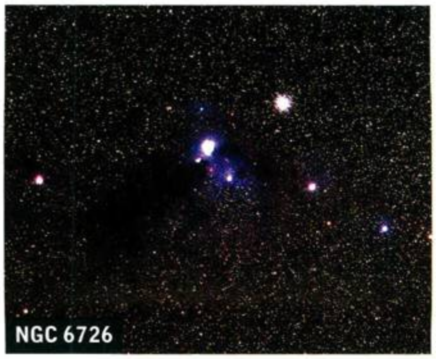
Pan 2° to the northeast and your scope will lock on **Palomar 12**, a very faint globular cluster more than 60,000 light-years away. It is suspiciously young, as much as 40 percent younger than the majority of the Milky Way's globular clusters. Motion studies suggest that Palomar 12 may have originated in the Sagittarius Dwarf Galaxy, but was later captured by the Milky Way. You'll need at least 8 inches of aperture to see Palomar 12. A 13-inch telescope brings out a faint, uniform haze just over 1' across. Palomar 12's brightest stars are barely brighter than 15th magnitude.

Tom Polakis is an aerospace engineer and observer living in Tempe, Arizona.



NGC 6907

James R. Foster



NGC 6726

George Greaney

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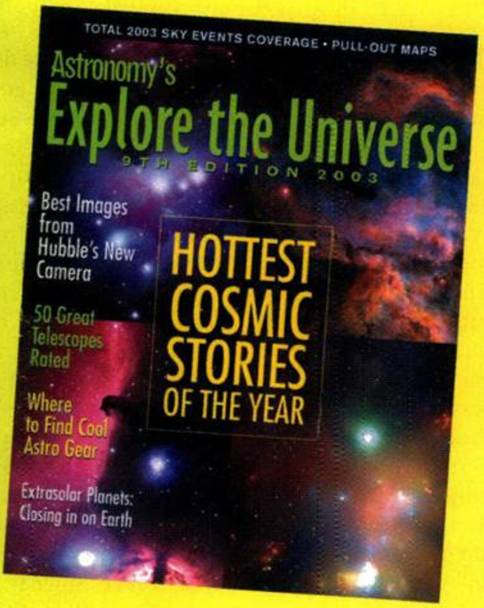

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Beginner's sky

Diary of a neophyte astronomer. by Jerry Burstein

This past month I've been part of two relatively rare events in one's lifetime. The neat thing was that one helped celebrate the other.

The recent, beautiful lineup of the five naked-eye planets — widely visible last in 1940 and which won't happen again until 2040 — occurred during a family gathering celebrating my parents' 50th wedding anniversary. The Florida panhandle was the setting for this four-day function.

One night my sidekick and I, armed with our 10x50 binoculars, were able to elicit what we fondly named "the call of the astronomer." You know — the "oohs" and "ahhs" of family and friends impressed with some newly discovered knowledge of this great hobby.

There we were on the beach (surprisingly with very little light pollution) shortly after sunset, toasting my mom and dad on their special day when my daughter excitedly exclaimed, "There's Venus and there's Jupiter. That's Saturn." Later on she picked out Mars and Mercury. Armed with a sky chart and our red light, we quickly were able to prove to our small audience that indeed she was correct. Talk about a proud moment (Ooh . . . ahhh)!

Using beach chairs with armrests, we were able to somewhat steadily focus our binoculars for a better look at a really bright Jupiter. (Sure wish I had brought our binocular mount.) We took turns getting a good look at it, and think we saw a couple of jovian moons (Ganymede and Callisto?). Further down to Jupiter's lower right, we spotted the yellowish glow of Saturn and also took a closer look at it. (We couldn't see the rings).

We caught the dim orange of Mars with our naked eyes but had a difficult time finding it in the binoculars. Quickly though, we found the bright light of Venus. Again, using the chart we verified Mercury, low in the sky, but had a difficult time seeing it better. I amazed all by correctly identifying and focusing in on the Pleiades, which was really cool to see.

We had a wonderful time taking turns, seeing what we could see, laughing and wondering out loud with my parents if they ever thought this is what they'd be doing 50 years to the night of their wedding. Over the next few nights, I was pleasantly surprised as some of the family wanted to go back to the beach and gaze into the skies again. It was interesting as we noticed how the planets seemed to have changed places, with Mercury and Venus appearing to move up higher into the sky and the rest lower. I discovered that because the inferior planets (Mercury and Venus) orbit the sun faster than Earth, they moved away from the sun and so appeared higher in the twilight sky from one night to the next. Meanwhile, Mars, Jupiter, and Saturn — which all orbit the sun more slowly than Earth — appeared to be descending toward the horizon as the month progressed. From Earth's vantage point, they all happened to line up in a spectacular planetary parade.

Welcoming the Perseids

As far as August goes, we're really excited about the upcoming show spread over August 12 and 13. The Perseid meteor event is a great first shower for beginners and perhaps the best to observe because of the amount of zenithal activity (hourly rate between 50 and 100 meteors). Unfortunately, the weather in Wisconsin didn't cooperate that well for the spectacular Leonids seen around the country in November 2001, so I'm hopeful the weather for the Perseids will be better.

August has had a reputation for the richness of its meteor displays throughout history. The Chinese made the first written reports of a Perseids Meteor Shower in 36 A.D. Observers from other Asian cultures tracked the Perseids from the 8th century through the 11th century. The Perseid shower has also sometimes gone by the name of the "Tears of St. Lawrence" since the meteors seemed particularly abundant on this saint's day, August 10.

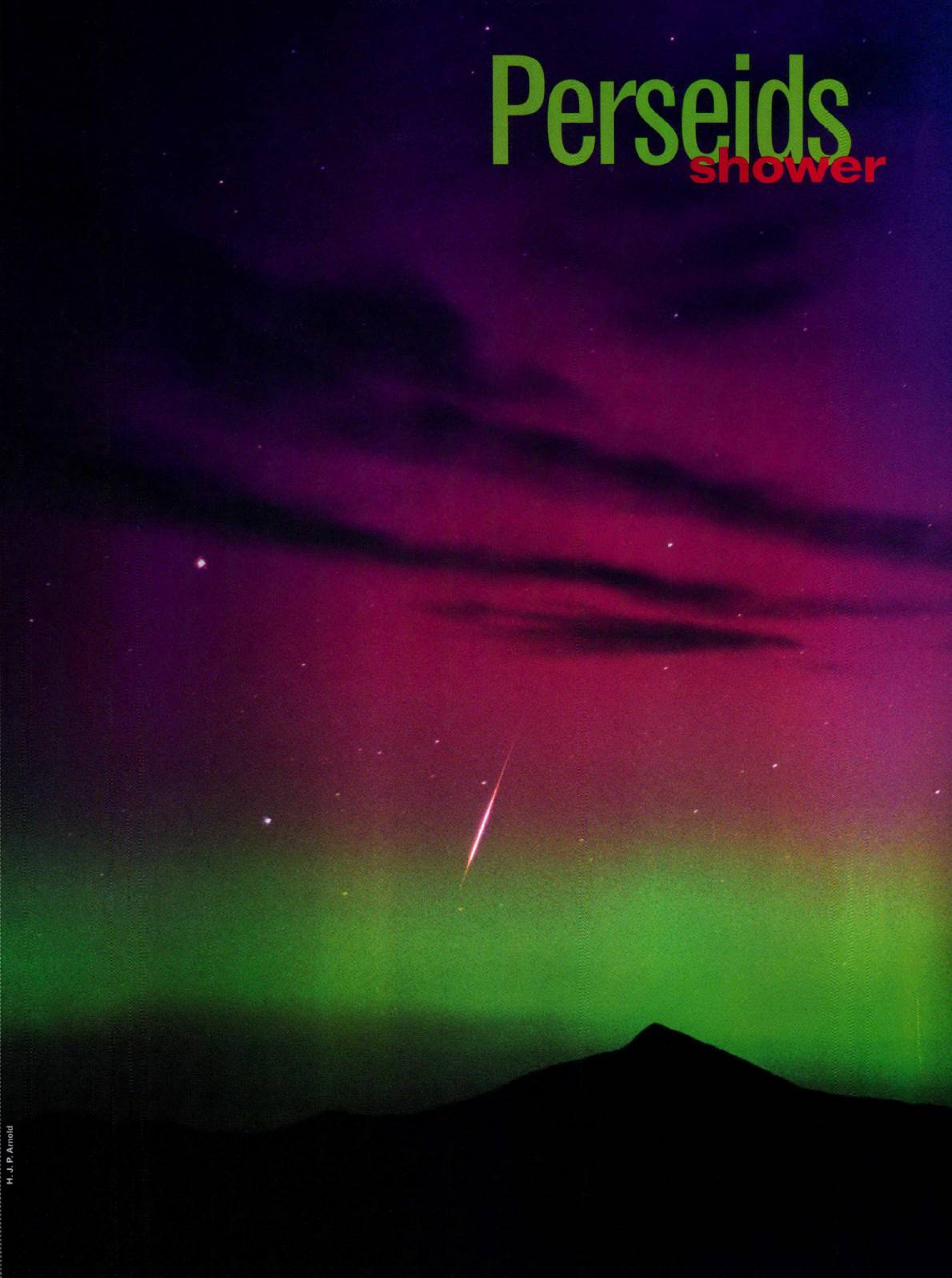
Please see "Sky Show," page 52, for a map of the Perseid Radiant and when to watch for the 2002 Perseids Meteor Shower. See Bob Berman's column "Strange Universe," on page 88, for more wisdom and fine advice about the Perseids.

Anyway, it's summertime, so grab a lawn chair, your favorite beverage, some insect repellent, and make your way outside late in the evening or early morning to check out the sky. It should be fun. For more information and helpful hints, go to www.astronomy.com.

A special thanks to everyone who participated in the many different Astronomy Day events this past spring. What a great way for "newbies" to discover more about this wonderful hobby. It's also a super time for clubs and groups to promote the fun of astronomy. We at *Astronomy* magazine were proud to provide materials used at several of these events and would be glad to continue to offer our support. Just e-mail me at jerry@astronomy and let me know how we can help.

Clear skies!

Perseids shower



cut along dotted line

H. J. P. Arnold

Collimating a newtonian reflector

by Phil Harrington

There is nothing more frustrating or disappointing to an amateur astronomer than to use a telescope that doesn't work as expected. All too often we are quick to blame the poor images on faulty optics or poor workmanship, but this is not necessarily the case. While some telescopes are lacking in quality, most work just fine if they are properly aligned. Even with the finest optics, a telescope will show nothing but poor images if those optics are not collimated correctly.

The optics in some types of telescopes are apt to wiggle out of alignment more easily than others. Newtonian reflectors are notoriously easy to knock out of alignment and so should be checked often. A Newtonian is collimated when the telescope's optical axis passes from the center of the primary through the center of the eyepiece. In practice, when we look through the telescope's focuser, the reflection of the primary mirror's full diameter appears centered in the secondary mirror.

On the next clear night, take your telescope outside and center it on a bright star using high magnification. Place the star slightly out of focus and take note of the diffraction rings that result. If the telescope is properly collimated, the rings should appear concentric around the star's center. If, however, the rings appear oval or lopsided — and remain oriented in the same direction when you change the focus to either side of best focus — then the instrument is in need of adjustment. Although the collimation procedure can be done at night, it's best to wait until the light of day so you can see exactly what goes where, since some disassembly may be required.

Here's how to collimate a Newtonian reflector. By following these steps today, you will have a better telescope tonight.

1 The first step involves a purchase. You need what is called a "sight tube," which is nothing more than a long, empty tube with a pair of crosshairs at one end and a precisely centered pinhole at the other. Site tubes usually cost about $30 to $50. The outer diameter of the sight tube must match the inside diameter of the telescope's eyepiece holder (typically, 1 1/4").

2 The next step is to check that the center of your telescope's primary is marked. If your telescope's mirror has a centered dot, then skip to Step 5; otherwise, you will need to mark it yourself. To do this, the mirror and its mounting cell must be removed from the bottom of the tube. Most cells are held in the tube by three or four screws protruding through the tube's side. Lay the telescope on a bed or sofa and slowly loosen each of these screws, making certain that you are holding onto the back of the mirror cell to prevent the cell and mirror from falling or rolling into the tube. With all screws removed, slowly extract the mirror and cell from the tube, being especially careful not to touch the mirror's surface. Mark each hole in the cell and on the tube so that you can line each up again in the same orientation afterward.

3 Place the mirror, still in the cell, on a large piece of tissue paper and trace its diameter with a pencil. Cut out the tracing precisely along its edge. Fold the paper circle in half, then in half again so that you end up with a 90° wedge. Snip off the tip of the wedge with a pair of scissors and unfold the paper. The resulting hole marks the center of the mirror tracing.

4 Using the tracing as a template, make a tiny mark at the center of the mirror with a "permanent" felt-tip marker. Carefully check the spot's accuracy with the ruler, and if acceptable, stick an adhesive-backed hole reinforcer (the kind used to strengthen looseleaf paper) on the mirror around the black dot. Don't worry about this central spot blocking part of the primary. It's located in the shadow of the secondary and never sees light anyway. Reinstall the primary in the reverse order that you removed it.

5 Look through the focuser (without an eyepiece) and identify all of the parts shown in Panel A of the illustration. You ought to see at least part of the primary and the far end of the telescope tube.

6 Aim the telescope toward a bright scene, such as the daytime sky (but not at or near the sun) turn the focuser in as far as it will go, insert the sight tube, and take a look. You should see the diagonal mirror centered in the sight tube's crosshairs. If it is, skip to the next step; if not, then move to the front of the telescope tube and look at the back of the diagonal mirror holder. Most Newtonians use a four-vane spider mount to hold and position the diagonal in place. Spider mounts typically grasp the diagonal in a holder supported on a central bolt. Loosen the nut holding the bolt in place and move the diagonal in and out along the optical axis until its outer diameter is centered in the sight tube (Panel B). Before tightening the nut, check to make sure that the diagonal is not turned away from the eyepiece, since it can also rotate as it is moved.

7 For the diagonal to be adjusted correctly, the primary must appear centered. To do this, most spider mounts have three equally spaced screws that, when turned, pivot the diagonal's angle. By alternately loosening and tightening the screws, pivot the diagonal mirror until the primary appears centered in the sight tube, as shown in Panel C.

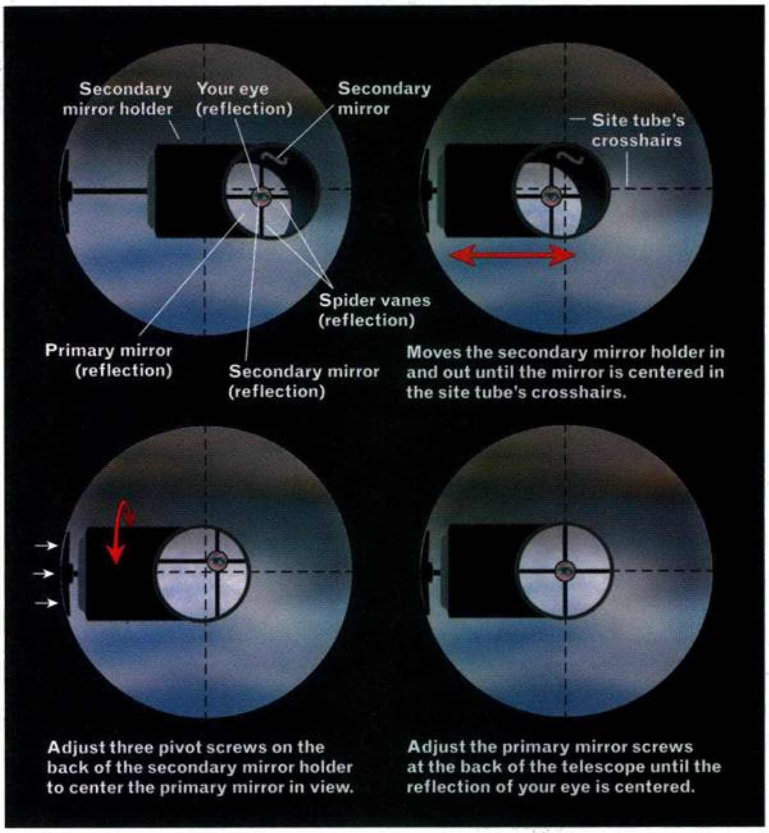
8 Aligning the primary mirror will go much faster if you have an assistant. First, look at the back of the primary mirror's cell. You should see three (sometimes six) screws facing out. These adjust the tilt of the primary. Each works a little differently to accomplish the same thing. Cells with three adjustment screws rely on stiff springs to press outward against the cell's plates to keep the mirror in position. Those that use six screws, called "push-pull" cells, are set up in pairs. One screw in each pair (usually the inner one) adjusts the mirror, while the other prevents the mirror from rocking. If your telescope uses this type of mirror mount, the three outer screws must be loosened slightly before an adjustment can be made.

9 With your helper at the adjustment screws, look back through the sight tube. You should see the reflection of the primary centered in the crosshairs (Panel D). In bright light, the primary's central spot should also be seen. Following your instructions, have your assistant turn one or more of the screws very slightly. Did the primary's reflection move a little? If so, did the reflection of the center dot move closer or farther from the sight tube's crosshairs? If closer, then have your assistant continue turning the screw in the same direction; if not, then turn the screw back to where it was and try another one. Continue turning the screws in and out until the reflected image of the center dot and your eye in the diagonal mirror appear centered. Again, do this step slowly and deliberately.

10 If you own an f/6 or slower Newtonian (that is, its focal ration is 6 or higher), the mirrors should be collimated adequately. If, however, your Newtonian is below f/6 — considered a "fast" f-ratio — then some fine-tuning will be needed. For this, another tool, called a Cheshire eyepiece, is strongly recommended. The Orion Telescopes collimating tool combines a sight tube and a Cheshire eyepiece, giving you both tools in one.

A Cheshire eyepiece (really a misnomer since no lenses are involved) has a large hole in its side and, inside, a shiny 45° face. By shining a flashlight through the hole, light will bounce from the Cheshire eyepiece to the secondary mirror, then to the primary mirror, back to the secondary, and out through the small peephole in the Cheshire.

For the final collimation adjustment, shine a flashlight beam into the Cheshire's side opening and look through the peephole. Centered in the dark silhouette of the diagonal will be a bright donut of light — the reflection of the Cheshire's mirrored surface. The dark center is actually the peephole in that surface. Adjust the primary mirror until the mirror's black reference spot is centered in the Cheshire eyepiece's donut.



Moves the secondary mirror holder in and out until the mirror is centered in the site tube's crosshairs.

Adjust three pivot screws on the back of the secondary mirror holder to center the primary mirror in view.

Adjust the primary mirror screws at the back of the telescope until the reflection of your eye is centered.

With the telescope collimated, take it back out on the next clear night and let the optics fully adjust to the outside air temperature. Using a medium-power eyepiece, place a moderately bright star in the center of the field. Defocus the image until it is transformed from a point into a tiny disk surrounded by bright and dark rings. If the mirrors are properly collimated, then the rings should look concentric, like a bull's-eye. If not, one or both of the mirrors may need a little tweaking. Be sure to recenter the star in the field every time an adjustment is made.

No doubt about it, a well-collimated Newtonian will show dramatically improved views over an identical telescope whose only flaw is maladjusted optics. So, if your Newtonian isn't focusing quite as sharply as you might like, don't immediately assume poor optical quality. It might just need a little TLC.

Companies that sell the collimating tools mentioned in this article:

Apogee. Inc
P.O. Box 136
Union, IL 60180
Ph.(877) 923–1602; (815) 568–2880
Website:www.apogeeinc.com

AstroSystems, Inc.
124 N. Second Street
LaSalle, CO 80645
Ph. (970) 284–9471
Website: www.astrosystems.biz

Orion Telescopes and Binoculars
P.O. Box 1815
Santa Cruz, CA 95061
Ph. (800) 447–1001, (831) 763–7000
Website: www.telescope.com

Tectron Telescopes
5450 NW 52 Court
Chiefland, FL 32626
Ph. (352) 490–9101
Website: www.amateurastronomy.com

Watching a Celestial Ballet

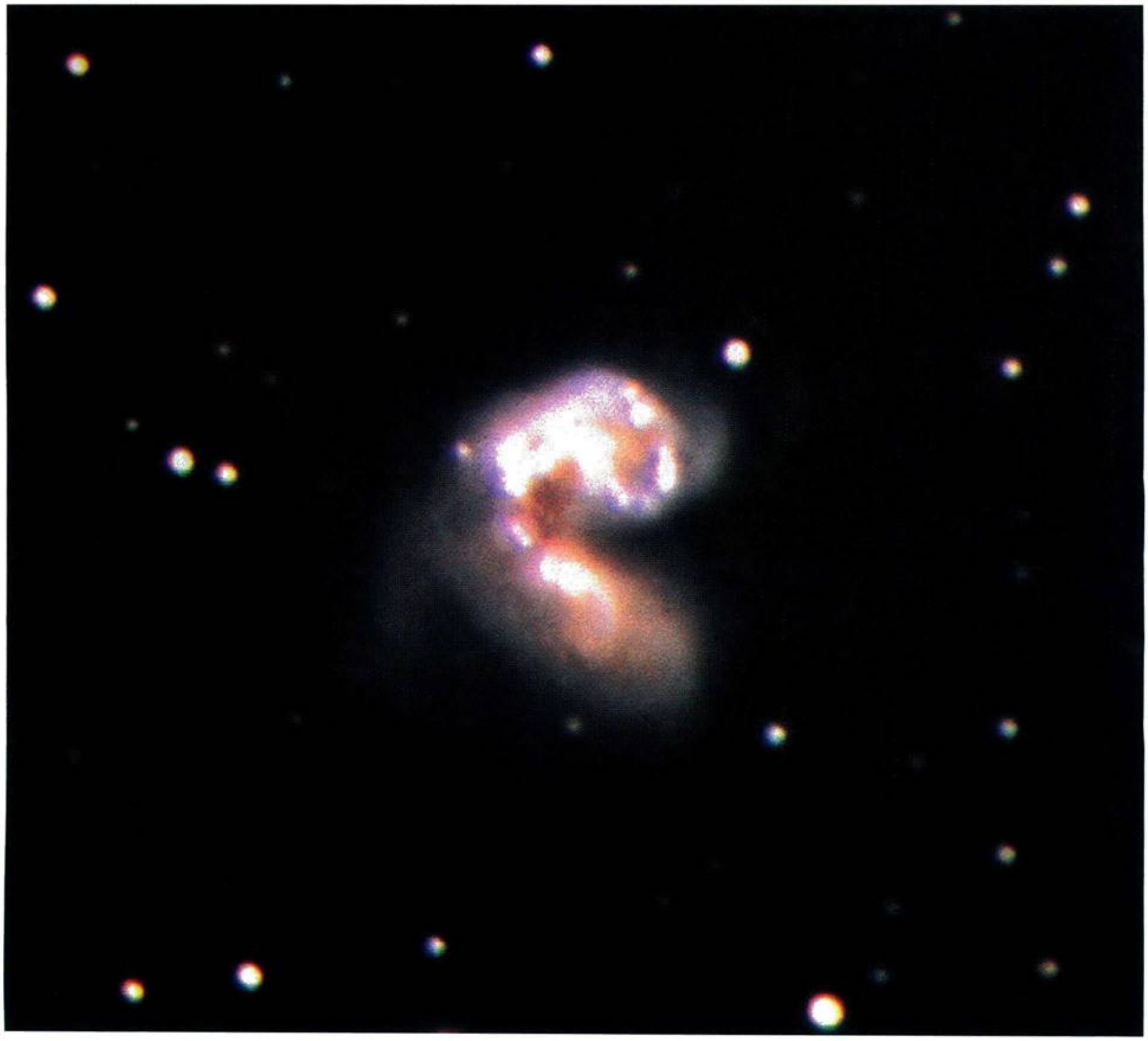
by Alan Goldstein

We live in a crowded universe. While most galaxies seem to be separated by vast distances, their enormous sizes and masses make galactic collisions and grazes regular events. Even for those objects not locked in embrace, gravitational tugs create a dance between celestial partners that can disrupt the stars and gas within them. This intergalactic ballet is beautiful but agonizingly slow, taking hundreds of millions of years from opening to curtain call.

Fortunately, our sky is littered with so many galaxies that we can see interactions between some at any given phase of the development of the universe. At present, enough interacting galaxies are visible to enable astronomers to understand the dynamics of these encounters. The deepest images of the universe, the deep fields taken by Hubble and selected ground-based telescopes, show that even more galaxies or protogalaxies were interacting in the distant past. This lends strong support to the idea that most galaxies evolved by repeated mergers.

The gravitational effects of galaxy interactions create a wide range of results. Massive galaxies seem to enlarge by cannibalizing other, smaller galaxies. Lenticular (lens-shaped) galaxies are believed to be spiral galaxies stripped of gas by collisions, which dramatically reduce star formation. Some astronomers propose that spiral arms are related to old galactic encounters.

The Hubble classification of galaxies (and its modifications by later astronomers) lists eight progressive galaxy types: regular spirals (type SA), transition spirals (SAB), barred spirals (SB), lenticulars (S0), barred lenticulars (SB0), ellipticals (E), irregulars (I) and the rare "peculiars" (P), which



The Antennae (NGC 4038/4039) are visible in any scope. James McGaha and Tim Hunter

Messier's Interacting Galaxies

Designation	Arp	R.A.(2000.0)Dec.	Galaxy	Interaction
M31/M32/M110	168	0h42.7m, 40°52'	Sb /dE	1
M51	85	13h29.9m, 47°12'	SAc / Pec	3
M60	116	12h43.7m, 11°33'	E0 / SABc	1
M65/M66/NGC 3628	317	11h18.9m, 13°06'	Sab	2/1
M96/M95/M105	—	10h46.8m, 11°49'	SABab/SBb/E1	1/0
M90/IC 3567	76	12h36.8m, 13°10'	SA/SB?	1

seem to be highly distorted. Fortunately, many of these types offer galaxies bright enough to be observed with backyard telescopes, and some of these specimens are interacting. The Messier catalog, typically the first deep-sky list that beginners turn to, contains several famous and not so well-known interacting galaxies. The Whirlpool Galaxy (M51) in Canes Venatici might be considered the prototypical interacting galaxy.

Observing Galaxy Interactions

A moderate-sized backyard telescope of 8 or 10 inches aperture shows a range of interacting galaxies, from casual interaction with minimal gravitational influence to "head-on collisions" with two galaxies merging into one. Although he wasn't the first astronomer to study such systems, Halton C. Arp created a catalog, *Arp's Atlas of Peculiar Galaxies*, which has become the standard for amateur astronomers. The original atlas is out of print, but if you could benefit from using this guide, you can now find it posted on the web at: http://nedwww.ipac.caltech.edu/level5/Arp/frames.html.

No official system exists for rating the degree of interaction between galaxies. For the sake of convenience, I use a 0–5 scale: 0 = no interaction; 1 = proximity for minor gravitational influence (not observable visually) — effects are limited to the outer halos; 2 = mild distortion (only one of the galaxies shows any effect); 3 = moderate distortion (both galaxies show effects, although they may not show them equally); 4 = heavy distortion (both galaxies show effects of strong tidal forces); 5 = extreme distortion (galaxies are often indistinguishable from one another).

Once you have the will to observe interacting systems and know what you're going after, it's easy to find some bright examples. Among the more commonly observed trios of galaxies are the **Andromeda Galaxy** (M31) and its two bright companions, M65 and its associates, and the M95 trio. All these are examples of interaction with minimal influence to the galactic structure of the partners, rating them between 1 and 2 on my scale.

In the case of M31, the galaxy's mass is so much greater than **M32** or **M110** (NGC 205) that the smaller galaxies' influence is almost inconsequential. In 7x50 or 10x80 binoculars and most small scopes, the Andromeda Galaxy and its companions are readily visible. M110 is the most challenging of the three because it does not have a pronounced central hub like the other two. With a 6-inch rich-field telescope, the view of the three galaxies can be quite a sight. Even with a small instrument, the bright glow of M32 next to the Andromeda Galaxy's disk makes quite a lasting impression.

The Leo galaxies **M95**, **M96**, and **M105** form a gravitationally bound group with minimal effects from their proximity to one another, a "type 1" interaction. M95 is a barred spiral of type SBb. M96 is a transitional barred spiral (SABab) and M105 is an E1 elliptical (almost round). Near M105 lie NGC 3384 (SB0) and NGC 3389 (SAc), galaxies which are also members of this group.

More bright galaxies in Leo, **M65** and **M66**, form a trio with the edge-on galaxy **NGC 3628**. The effects of the interaction in this group are largely visible on M66 alone (type 2), with its asymmetrical, clumpy, "S"-shaped arms. Although it is highly inclined to our line-of-sight, M65 shows no apparent distortion (type 0). NGC 3628 is the most distant of the three. It is a spiral whose edge-on dust lane angles diagonally across the disk (type 1 or 2). It's possible that in a hundred million years the interaction will become more pronounced.

Leo also contains a favorite of mine, **NGC 3226/3227** (Arp 94). This type 2 pair consists of an SABa (early transition barred spiral) nearly in contact with a slightly oval E2 type galaxy. The curious nature of this pair is exaggerated by the bright nuclear region of the spiral. The small, star-like core results from the galaxy's explosive nature as a Seyfert, one that is probably powered by a supermassive black hole.

Moving over to Cancer brings you to **NGC 2623** (Arp 243), an object that may have been two barred spirals before the cosmic train wreck. These galaxies have flagellate-like arms projecting in opposite directions from the tangled structure of their central hubs. This magnitude 13.8 object requires a large scope and good skies to see. Visually observing the extended arm structure is probably beyond even large amateur telescopes.

Canes Venatici, tucked near the Big Dipper, contains a raft of interacting galaxies. The **Whirlpool Galaxy** (M51) is the classic interacting galaxy (type 3) with conspicuous arms, one reaching to the smaller companion, NGC 5195. The companion is a dusty, peculiar galaxy, possibly stirred up by the encounter. One of the challenges of observing this pair is to find the arm connecting it. Can you see a glow that bridges the gap? The fan-shaped structure in NGC 5195 is also difficult to observe.

Within the small constellation lies **NGC 4490** and its smaller companion **NGC 4485**, another type 3 interaction. This pair, known as Arp 269, is unusual because it offers a large, particularly bar-shaped irregular galaxy (4490) interacting with a smaller spiral galaxy. Visually, the larger one appears somewhat rectangular, while NGC 4485 is round and offset from the long axis.

To the south, in Corvus, lies the **Ringtail Galaxy**, NGC 4038/4039 (Arp 244). This object consists of a pair of heavily distorted galaxies that resembles a hook or "9." NGC 4038 is a ring galaxy; the tail is formed by NGC 4039, possibly a small barred spiral galaxy with a central core. This object was made famous by a Hubble Space Telescope image that has served as a backdrop in a number of movies, such as the closing scenes of *Galaxy Quest*. It is the brightest type 5 interacting pair in the sky, at magnitude 10.3, and the odd structure is readily visible in a 4-inch or 6-inch scope.

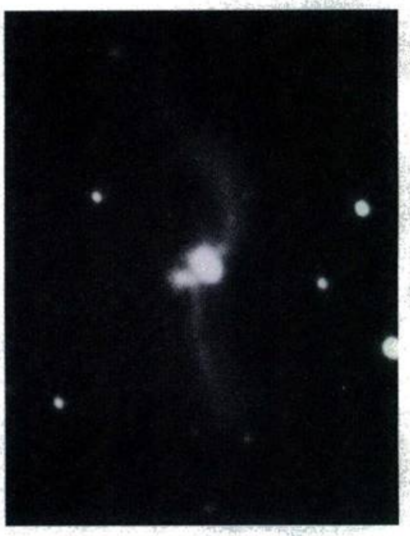
Virgo holds the interacting pair **NGC 4567/4568**, sometimes called the Siamese Twins because the galaxies appear to be connected at one end. Both are spirals with only moderate amounts of distortion visible in photographs (type 2). Visually the two appear as an oval and a round circular patch in contact.

NGC 2992/2993 (Arp 245) in Hydra is a faint, fascinating object with type 4 interaction. We see two spirals (or perhaps a spiral and a lenticular galaxy), each with major distortions forming a single whip-like outer arm. In medium-sized scopes, NGC 2992 appears elongated while NGC 2993 is somewhat more rounded. In a 24-inch scope, a clump of stars at the end of the "arm" extending from NGC 2992 is visible as a moderately large, very faint glow. Next to NGC 2992, you can observe the 16th-magnitude quasar Weed-

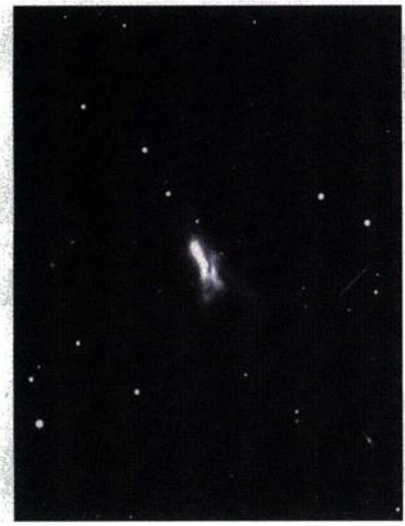
The Best Interacting Galaxies

Designation	Arp	R.A.(2000.0)Dec.	Galaxy Types	Interaction Type
NGC 274/275	140	0h51.1m, –7°04'	SAb?/E0	4
NGC 520	157	1h24.6m, 3°48'	S/?	5
NGC 750/751	166	1h57.5 m, 33°13'	E/E	3
NGC 772/0	78	1h59.3m, 19°00'	SAb/dE	3
NGC 1097/1097A	77	2h46.3m, –30°16'	SBb/dE	1
NGC 1532/1531	—	4h12.1m, –32°52'	Sb/SO	1
NGC 1812/1811	—	5h08.9m, –29°16'	SAa/SAa	2
NGC 2207/IC 2163	—	6h16.4m, –21°22'	SABc/SBc	3
NGC 2623	243	8h38.4m, 25°45'	SBc/SBc	5
NGC 2992/2993	245	9h45.7m, –14°20'	SO/SAd?	4
ESO 316–12	—	10h09.1m, –38°25'	SBb (Ring)/E?	4
NGC 3100/3095	—	10h00.7m, –31°40'	SAB0/SABc	3
NGC 3226/3227	94	10h23.5m, 19°05'	SABa/E2	2
NGC 3347/3354/3358	—	10h42.8m, –36°22'	SBbc/SAbc/SBab	2
NGC 3395/3396	270	10h49.8m, 32°59'	SABcd/IBm	3
NGC 4038/4039	244	12h01.9m, –18°52'	SBc?/SBd?	5
NGC 4298/4302	—	12h21.5m, 14°36'	SAc/SAc	2
NGC 4435/4438	120	12h27.8m, 13°01'	SBO/SO/a	3
NGC 4490/4485	269	12h30.6m, 41°38'	SBd/SABm	3
NGC 4568/4567	—	12h36.6m, 11°14'	SAbc/SAbc	2
NGC 4618/4625	23	12h41.5m, 41°09'	SBm/SABm	3
NGC 4631/4627	281	12h42.1m, 32°32'	SAc/dE	1
NGC 4762/4754	—	12h52.9m, 11°14'	SB0/SB0	<1
NGC 4783/4782	—	12h54.6m, –12°33'	SO/SO?	2
NGC 5395/5394	84	13h58.6m, 37°25'	SAc/SBc	3
NGC 5427/5426	271	14h03.4m, –06°02'	SAc/SABc	2.5
NGC 5566/5560/5569	286	14h20.3m, 3°56'	SBab/SBb /SABcd	3 to 3.5
NGC 6621/6622	81	18h12.9m, 68°22'	SB/S?	4 to 5
NGC 7236/7237	169	22h14.8m, 13°51'	SAO/SAO	3

For objects with more than one number, the brightest galaxy designation is listed first. Coordinates are for the brightest galaxy. In some cases the morphological type has been estimated because of the high degree of tidal distortion involved. Scale of interaction: 0 = no interaction; 1 = proximity for minor gravitational influence (not observable visually) — effects are limited to the outer halos; 2 = mild distortion (only one of the galaxies shows any effect); 3 = moderate distortion (both galaxies show effects, although they may not show them equally); 4 = heavy distortion (both galaxies show effects of strong tidal forces); 5 = extreme distortion (galaxies are often indistinguishable from one another).



NGC 2623 in Cancer consists of two intertwined galaxies. James R. Foster



Galaxy clump NGC 520 in Pisces meets asteroid 3726 (right edge). Kim Zussman

Fornax is home to the galaxy pair NGC 1097 and NGC 1097A. Preston Scott Justis

man 2, visible with averted vision.

Look to Pisces to find **NGC 274/275** (Arp 140), a small, faint pair consisting of an elliptical galaxy colliding with a spiral. The spiral shows major distortion by tidal forces from colliding with the more massive elliptical, and its arm structure is completely disrupted, forming a heart-shaped structure. In a 13-inch scope at moderate power, the two appear to be in contact.

Also in Pisces lies one of the most distorted bright galaxies in the sky, **NGC 520** (Arp 157) — a classic type 5. In a telescope, its shape resembles a shoe. A splash of bright stars, the result of the collision, stretches in opposite directions like debris from a head-on crash. In a hundred million years this galaxy might appear to be a single distorted object, eventually coalescing into a massive spiral.

One of the lesser-known southern beauties is **NGC 2207/IC 2163** in Canis Major. NGC 2207 shows a round patch with a bright nucleus. IC 2163 appears oval without much central brightening. Photographs reveal a clumpy spiral structure with two asymmetrical arms and a tadpole-shaped barred spiral in contact. This is a type 3 with moderate distortion, with IC 2163 looking much worse from the collision.

Way up north, **NGC 6621/6222** (Arp 81) in Draco shows type 4 distortion. The larger galaxy has a massive arm wrapped around its distorted, bar-like central hub. It was probably originally a barred spiral. The smaller galaxy was probably a normal spiral, but the tidal forces of the collision have disrupted its form to something irregular.

In the dance between galaxies we see the largest collisions in the universe. Our own Milky Way has swallowed as many as 100 smaller companions. It will no doubt do so again, as with the Magellanic clouds. A couple of billion years from now, our galaxy and M31 will commence their celestial tango. If only we could stick around to watch it, the result would be quite a remarkable show. Short of that, we can see celestial dances among other galaxies happening on any clear night. ■

Alan Goldstein is founder of the National Deep Sky Observers Society and a longtime contributor to Astronomy.

Challenging Comets/August 2002

In any month, usually several comets glow brightly enough to become visible to those with large telescopes. Here are coordinates and magnitudes:

22P/Kopff

Aug. 1	12h41.1m, 0°03'	12.9
Aug. 11	12h57.7m, –1°55'	12.6
Aug. 21	13h15.7m, –4°00'	12.3
Aug. 31	13h35.2m, –6°09'	12.0

7P/Pons-Winnecke

Aug. 1	0h38.2m, –39°37'	12.2
Aug. 11	0h38.5m, –42°41'	12.6
Aug. 21	0h32.6m, –45°02'	13.0
Aug. 31	0h22.0m, –46°27'	13.5

C/2002 C1 (Ikeya-Zhang)

Aug. 1	15h33.4m, –8°13'	12.4
Aug. 11	15h40.3m, –10°12'	12.9
Aug. 21	15h48.3m, –11°55'	13.4
Aug. 31	15h57.1m, –13°24'	13.8

C/2001 RX14 (LINEAR)

Aug. 1	5h28.0m, 44°15'	13.7
Aug. 11	5h52.1m, 45°29'	13.5
Aug. 21	6h17.5m, 46°36'	13.3
Aug. 31	6h44.3m, 47°35'	13.1

C/2001 N2 (LINEAR)

Aug. 1	16h02.3m, 6°36'	13.5
Aug. 11	15h45.4m, 3°05'	13.7
Aug. 21	15h33.3m, –0°06'	13.8
Aug. 31	15h25.2m, –2°56'	14.0

C/2002 F1 (Utsunomiya)

Aug. 1	8h00.0m, –27°41'	13.6
Aug. 11	8h15.6m, –31°32'	14.0
Aug. 21	8h30.5m, –35°21'	14.4
Aug. 31	8h44.7m, –39°07'	14.7

C/2002 E2 (Snyder-Murakami)

Aug. 1	13h04.0m, 74°51'	13.9
Aug. 11	13h10.9m, 73°38'	14.1
Aug. 21	13h22.1m, 72°42'	14.4
Aug. 31	13h36.8m, 72°02'	14.6

PRODUCTS

Nagler Type 6 Eyepieces

Four more Nagler eyepieces — 13mm, 9mm, 7mm, and 5mm — are available from Tele Vue Optics. These brand-new, seven-element oculars feature 12mm eye relief, an 82° apparent field of view, and advanced glass and coating technology. All are conveniently parfocal with Tele Vue 1¼-inch Plössl, Panoptic, and Radian eyepieces and are compatible with other focusers and binoculars that accept that size as well. These eyepieces offer excellent contrast and full-field sharpness when used with telescopes of any size or focal ratio, making them the perfect tool for terrestrial, planetary, or deep-sky observing.

Features include fold-down eyeguards, rubber grip rings, anti-reflection threads, blackened lens edges, and more. Each eyepiece weighs about eight ounces (228g) and lists at $280.

Tele Vue Optics, 32 Elkay Drive, Chester, NY 10901; (845) 357–9522; website: www.televue.com.

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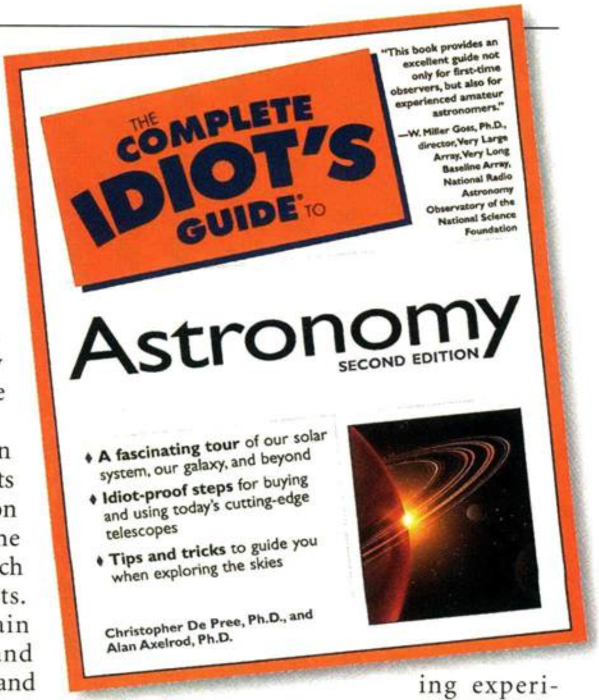
BOOKS

The Complete Idiot's Guide to Astronomy, Second Edition

Christopher De Pree and Alan Axelrod, 431 pages, Alpha Books, Indianapolis, 2001; ISBN 0–02–864198–1; softcover, $18.95.


"This book provides an excellent guide not only for first-time observers, but also for experienced amateur astronomers."
—W. Miller Goss, Ph.D., director, Very Large Array, Very Long Baseline Array, National Radio Astronomy Observatory of the National Science Foundation
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Idiot-proof steps for buying and using today's cutting-edge telescopes
Tips and tricks to guide you when exploring the skies
Christopher De Pree, Ph.D., and Alan Axelrod, Ph.D.

Astronomy can be complex and intimidating, filled with theories and formulas, yet *The Complete Idiot's Guide to Astronomy* is an easy-to-understand informational guide for beginner and advanced stargazers alike. Through lighthearted, refreshing text, astronomy professor Christopher De Pree and professional writer Alan Axelrod team up to provide a broad, comprehensive survey of the cosmos that is accessible to a general readership.

Written mostly for the relatively inexperienced astronomer, the book's 26 chapters do a good job of introducing astronomical concepts in a systematic, step-by-step manner. De Pree and Axelrod go beyond explaining basics such as meteors and constellations, and give readers a "state-of-the-universe" report. They also weave in some relatively advanced information like Schwarzschild radii and spiral density waves that would interest readers with a more advanced science background. The teaching abilities of both authors shine through with a straightforward and friendly approach, using simple language to introduce each new topic.

Each chapter begins with an "In the Chapter" box that points out the key concepts the section covers. At the end comes "The Least You Need To Know," which summarizes important points. Numerous boxes that explain space jargon (Star Words) and entertaining facts (Astrobytes and Close Encounters), make it perfect for even the browser.

The hallmark humor of the Idiot's Guide series, evident in the illustrations, puns, and cleaver subheads, adds to — instead of detracting from — the learning experience. Publishing deadlines notwithstanding, readers are introduced to recent findings such as the evidence of water on Mars or the mysteries of the expansion of the universe. Curiously, reports of breaking research news about such things as gamma-ray bursters and planetary conjunctions are missing.

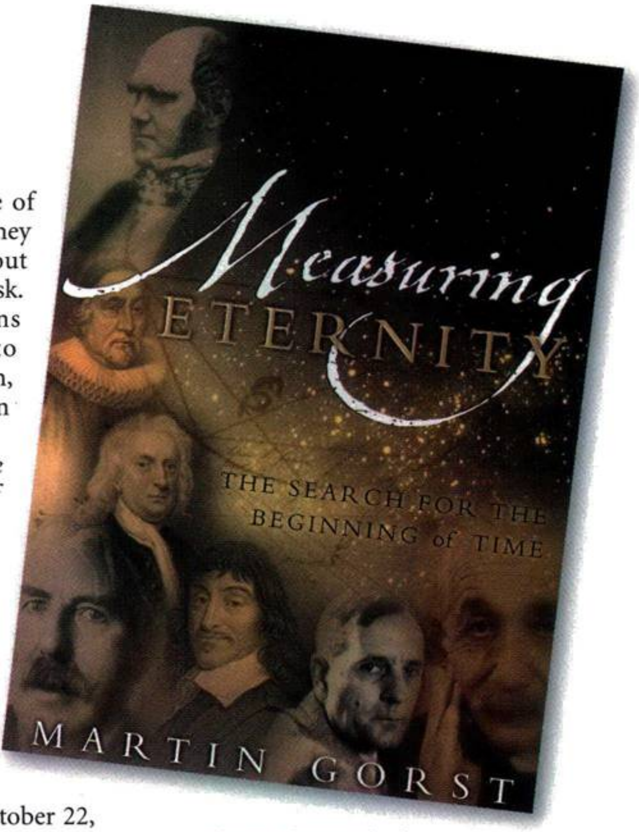
Although its pages are filled with terminology commonly used in modern astronomy, this guidebook is definitely not a dry college textbook. However, figures and diagrams that explain more abstract concepts would aid learners. Although the authors discuss groundbreaking images taken by Hubble, Chandra, and from Keck, all illustrations appear in black-and-white. There are, however, website addresses for interested readers who like to surf the Internet for the latest news and discoveries. One feature that is becoming quite common in the digital age is sorely missing in this book: a companion CD with related information and tools.

Despite some minor drawbacks, this is a great book for both the active and armchair astronomer. The authors should be commended on their efforts to cover everything from backyard astronomy to space-based telescopes in one volume. It's a daunting task to encompass all aspects of a science that is as broad and fast-paced as astronomy. For those who already own a copy of the first edition, there's no real need for the new one — although with its modest price, many may be tempted to purchase this second edition and pass along their used copy to a beginning stargazer.

For the space trivia buff, this refreshing guide offers a plethora of information. For those who gaze up at the night sky and wonder what's out there, *The Complete Idiot's Guide to Astronomy* provides many entertaining hours of enjoyment and easy learning. — *Andrew S. Fazekas is a science communicator based in Montreal, Canada.*

Measuring Eternity: The Search for the Beginning of Time

Martin Gorst, 338 pages, Broadway Books, New York, 2001; ISBN 0-7679-0827-9; hardcover, $23.95.



Look at your watch or your calendar. It's been two hours since lunch, one day since you went to the movies and a year since your last birthday. For most of us, measuring time is a relatively simple matter. We can project it forward or backward in the context of normal, everyday experience. But picture yourself in a world where you have no prior reference points, no knowledge of when things started or when they will end; then try to figure out reality — a most perplexing task. That's the challenge humans faced when they began to wonder about the age of Earth, the universe, and their own species.

Measuring Eternity: The Search for the Beginning of Time, traces this endeavor in a fast-paced approach that takes readers from the Old Testament to the Hubble Space Telescope and the inevitable conflict between religion and science. In 1649, Protestant Irish Bishop James Ussher confidently declared that Earth was created at 6 P.M. on Saturday, October 22, 4004 B.C. His reading of Genesis gave him the answer by tracing 21 long-lived generations between Adam and Eve in the Garden of Eden and Abraham. Since God created Heaven and Earth solely for humans, he believed, the planet and mankind had to be the same age. Mystery solved. But not for long.

Soon, European geologists began to wonder if rocks, not books, held the true secrets to the past. Their probes into different layers of sediment deposits and the mystifying discovery of marine fossils atop mountains far above the ocean beds set the stage for Biblical confrontations spanning centuries to come. In 1749, French naturalist Georges-Louis de Buffon calculated that Earth was at least 50,000 years old, but he quickly ran afoul of the Catholic Church. After retracting these "reprehensible propositions," Buffon quipped, "It is better to be humble than hanged."

Despite these barriers, curious minds prevailed and the frontiers of knowledge advanced, each time breaking further from the Bible to push back Earth's age. Scientists used every method imaginable in their search for reality. In the 1740s, Swedish astronomer Anders Celsius — better known for his temperature scale — studied sea level declinatons over a long number of years and concluded that Earth had been here a very long time. Celsius didn't know, however, that Scandinavia had been covered with heavy glaciers during the last Ice Age; ocean levels weren't falling — the land mass was simply rebounding. Good try!

Others used even more ingenious means, like measuring the salinity of seawater to figure out how long it had taken to get that much sodium into solution. Then came Englishman Charles Darwin, who published *The Origin of Species* in 1859. Darwin really upset the applecart by claiming that hundreds of millions of years were required for natural selection to work its evolutionary path, with human beings merely at the top of the food chain for the moment.

The latter parts of author Martin Gorst's enlightening book deal with recent discoveries that have established Earth's age at more than four billion years and the age of the universe itself at something around 14 billion years, give or take a few eons.

Gorst writes and directs TV science documentaries for the Discovery Channel and Britain's Channel 4. From his vantage point in England, he's learned enough to add this postscript: "The only certainty, if history has anything to tell us, is that this latest age for the universe won't be the last . . . we have only just begun to explore." — Nick Nichols is a retired news media relations manager for the Idaho National Engineering and Environmental Laboratory in Idaho Falls. — *Andrew S. Fazekas*

The Webweaver Picks

by Richard J. Bartlett

In 1965 the asteroid 1999 VP11 came within 248,000 miles (400,000 km) of the Earth — just a little further than our own moon. No one knew about this close encounter until 34 years later, but it could have caused a global catastrophe. 1999 VP11 is now classed as a Near Earth Object (NEO).

At the time of this writing, 1,904 NEOs are known, of which about a third are wider than a kilometer (just over half a mile). More than 400 of the known NEOs are larger than end-to-end football fields (200m) and come within 4.6 million miles (7.5 million km) of Earth. These are classed as Potentially Hazardous Asteroids (PHA). Asteroid 1999 VP11 is an example of a PHA.

Exactly what would happen if a comet or asteroid should hit Earth has been the subject of movies and television programs. If you want to know the facts behind the fiction, one of the best places to start is the Planetary Society's NEO site at http://neo.planetary.org/. Well designed and informative, it aims to educate those who want to learn more about NEOs and their dangerous cousins.

The Jet Propulsion Laboratory also has a site devoted to the study of NEOs at http://neo.jpl.nasa.gov/welcome.html. This basic but easy-to-use website is updated frequently with the latest facts and figures and contains a superb interactive page that displays and animates a specific NEO orbit. Both sites serve as excellent resources for information on the subject without the hype or dramatization so often portrayed in the media.

NASA's asteroid and comet impact site is http://impact.arc.nasa.gov. Easy to navigate, its valuable information gets updated regularly. Details of government studies and NASA programs can also be found at this site.

So what should you do if you find a lone asteroid wandering through our celestial neighborhood? How can you be sure it's not one of the NEOs already known? Try Lowell Observatory's Asteroid Data Services at http://asteroid. lowell.edu/. This text-only site provides an invaluable series of online scripts that generates ephemerides and basic charts for all asteroids and any NEOs requiring further observation. Especially handy is the astplot routine at http://asteroid. lowell.edu/cgi-bin/koehn/astplot. It generates a chart detailing which asteroids were passing through a specific area of sky on a given date. This is especially handy if your long-exposure astroimages leave a streak across the sky.

THE NEO PAGES
THE PLANETARY SOCIETY
HEADLINES

If you don't see your discovery listed with the Lowell Observatory, contact the Minor Planet Center at http://cfa-www.harvard.edu/cfa/ps/mpc.html. Report your sighting by following a link near the top of the page for new material. If you've found something, then it'll be listed on the NEO Confirmation Page for others to follow up. This is also the place to go if you wish to help in the hunt for minor planets.

Fortunately for us, many individuals and observatories are actively pursuing suspected NEOs. These include those responsible for the following websites: European Near-Earth Asteroids Search Observatories (euneaso) — http://earn.dlr.de/euneaso.htm; Czechoslovakia's Klet Observatory — www.klet.cz/; the Lincoln Near Earth Asteroid Research (linear) program — http://www.ll.mit.edu/LINEAR/; the Lowell Observatory Near Earth Object Search (loneos) — http:// asteroid.lowell.edu/asteroid/loneos/loneos_disc.html; the Near Earth Asteroid Tracking (neat) program — http://neat.jpl.nasa.gov/; Spaceguard — http://spaceguard.ias. rm.cnr.it/SGF/; and Spacewatch — http://pirl-www.lpl.arizona.edu-spacewatch/.

NEO PROGRAM
NASA
WELCOME

Most of these are pretty basic and text-heavy. Spaceguard is still under construction, and unfortunately this only highlights the fact that it's often hard enough to find the time and money to carry out valuable observational work, much less devote precious resources to maintaining a website.

If you've found a new asteroid, you're allowed to suggest a name for it. Over the years, many asteroids have been named after famous people or those who have excelled in their field of expertise. Rock music is no exception. The Minor Planet Center has pages devoted to such stellar dignitaries at http://cfa-www.harvard.edu/cfa/ ps/special-rocknroll/RockAndRoll.html.

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> I want to congratulate you on your website. It is easy to use, provides wonderful explanations of terms, and has been most helpful to me in my search for practical knowledge on the various products.
>
> **Customer Quote of the Month #125**

Eyepiece storage cases from \$2$^{\underline{49}}$.

Bolt-type containers protect eyepieces dew and dust. Foam inserts cradle eyepieces to protect them from accidents. Our website tells which eyepieces fit in which containers (including some other containers that are not listed below).

42mm x 60mm Holds most Celestron NexStar, Meade Series 3000, and TeleVue Plössls, etc.	\$2^{49}
52mm x 80mm Holds TeleVue Radians, Nagler Type 6, most Barlows, large Celestron Ultima, etc.	\$3^{49}
65mm x 80mm Holds most illuminated reticles, 22mm Panoptic, 12mm Nagler, etc.	\$3^{99}

The rave review multicoated NexStar 11 can be yours in a week.

NexStar 11 GPS
$2999

Celestron's 11" go-to computerized scope with multicoated optics – the **NexStar 11 GPS** – got a *rave* review in February's *Sky & Telescope.* The review gave it "an enthusiastic two thumbs up and a gold star." They said it has "Brains and good looks. The NexStar 11 GPS puts Celestron's time-tested 11-inch f/10 Schmidt-Cassegrain optics in a sleek new package that includes some of the most advanced electronics ever offered in a mass-produced telescope . . . Celestron is the first to take Go To scopes to the next step in their evolution, and it's a nice step indeed."

We have the NexStar 11 in stock (16 as this was written). Call us and you can be observing with yours in about a week.

The NexStar 8 GPS is multicoated for both CCD and visual observing.

NexStar 8 GPS $2499

The in-stock 8" **NexStar 8 GPS** (17 on hand as this was written) has Starbright high transmission multicoated optics for brighter images at no extra cost. You can easily convert its unique Fastar optics to a blazingly fast f/1.9 focal ratio for wide field CCD imaging.

With an optional Fastar lens assembly and a $1295 SBIG ST-237A CCD camera, the NexStar 8 GPS records a huge 32 x 42 arc minute field – larger than the full Moon and over three times the sky area imaged by a $7695 camera on other 8" scopes without Fastar! Of all GPS scopes, *only Celestron NexStars have multicoated Fastar optics!*

Compare Celestron go-to prices. Only $1499 for a multicoated 8" . . .

NexStar 8
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Compare the price of the **Celestron NexStar 8** go-to SCT with other 8" go-to scopes. At only $1499 – complete with adjustable height tripod, Starbright *multicoated* high transmission optics, red dot finder, 40mm Plössl eyepiece, and a computer with 18,000+ objects in its memory – it's priced hundreds of dollars less than other 8" go-tos. It's enough scope to keep you observing for the rest of your life, at a price that puts 8" go-to astronomy within the reach of practically everyone!

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You get a $149 adjustable height aluminum tripod (with built-in equatorial wedge), *multicoatings,* and a computer control *for free* when you buy a **Celestron NexStar 5** go-to SCT. Compare this $1149 price – *complete* – with other 5" go-to scopes that charge extra for an optional tripod, coatings, and computer and you'll see that Celestron saves you *nearly $200!* NASA uses 5" Celestron multicoated optics on the Space Shuttle. Don't your eyes deserve the same quality?

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One couple liked the two $450 list **Celestron/Tasco 8 x 42mm Rare Bird** roof prisms they bought from us so much that they bought seven more to give to their kids!

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A \$79$^{\underline{95}}$ cure for the refractor blues!

The **Sirius MV1-1** eyepiece filter reduces the annoying violet halos around bright objects in inexpensive achromatic refractors. *Sky & Telescope* said, "it will improve the view, especially of the Moon and planets."

Discovery Dobsonian reflectors start at only $339.

8" f/6 DHQ
$449

Why settle for an imported Dob when you can have made-in-the-USA quality *for less money!* Discovery doesn't use imported, mass-produced optics that are merely spot-checked to see if they're acceptable. Discovery optics are made in California by optical craftsmen, one quality mirror at a time. Each is hand figured to diffraction-limited performance, and it doesn't leave the Discovery optical shop until it's right.

Each DHQ series Dob has an adjustable metal primary mirror cell, a true *thin vane* adjustable 4-vane diagonal mirror spider, *two* Plössl eyepieces, a built-in tube balancing system, a tube carry handle, new oversized bearings, a 6 x 30mm finder, and a dust cover. You can get an upgrade kit that adds two more Plössl eyepieces, an eyepiece rack, a second dust cover, and a Moon filter for only $49 more!

Premium Dobs from 10" to 17.5" in aperture are also available. And for those who need big aperture portability, truss-tube Dobs are available in apertures from 12" to 24". Here are the Discovery 6" to 10" DHQ Dob prices:

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6" f/8 Discovery DHQ	\$339^{00}	plus $49 freight
8" f/6 Discovery DHQ	\$449^{00}	plus $49 freight
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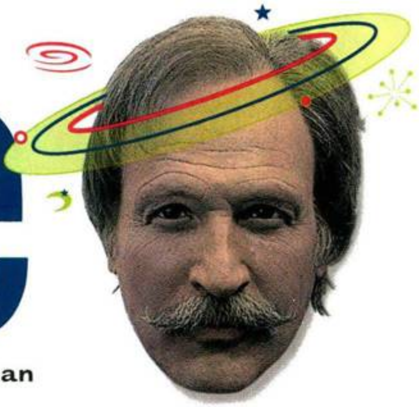

by Bob Berman

Meteoric Success

For the first time since 1999, the galaxy's most famous meteors flash across moonless skies this month. Perseid perfection!

Many remember the Perseids from childhood, from summer camp or vacations in the country. Because this shower coincides with warm air and freedom from school or work, and neither telescope nor binoculars are needed, August 11/12 is the sky's vox populi — the only annual celestial event widely observed by non-astronomers.

A surprising number of people ask if they'll see meteors if it's cloudy. This sounds stupid, perhaps, but not everyone realizes that meteors incandesce at a much higher altitude than clouds. Disintegrating above the stratosphere, even rare intact meteors slow down and cool so much that they totally stop creating light when 50 miles up — five times higher than passenger jets can cruise. If a meteoroid hits a cloud, it'll just darkly plunge through it and invisibly exit the bottom, unseen. That's why the common report of a "meteor coming down in the neighbor's field" is always an illusion.

The sky may seem clear, but haze or a thin cirrostratus layer is murder on meteors. Since the average apple seed-sized Perseid shines at magnitude 3, you can easily judge how many you'll miss in any given sky condition, including various degrees of light pollution. When the Milky Way goes unseen, half the shooting stars will also be invisible; the hourly rate will be cut to below 30. If only the brightest stars poke through cruddy haze, expect just a few meteors an hour.

Since lights are anathema to meteor watching, you'll want to get away from cities and streetlights and mall and yard lights, and even window lights. The ideal is to be in the country by a lake, in a field, or even in a cemetery — any dark place with no overhanging trees or obstructions. It's a no-brainer: the more sky, the more meteors.

But if perfection is not available, no need for Prozac. A few distant lamps or the glow from neighbors' windows won't do much harm. You're looking for animated meteors, not the long-awaited return of the Tau Ceti Mothership. Unless you're engulfed in heavy duty brightness, shooting stars can overpower the competition.

Say you've spread a blanket — always the best way to watch Perseids — and are out there with a date, friends, or family. Assume you have clear skies and a good location; you're set and the group is lying down. If they can handle one simple rule, everyone should be told to keep eyes glued upward. This is why lying prone is so important. When sitting on lawn chairs, people tend to keep looking at each other while conversing; they glance up only from time to time. This is the primary meteor-watching no-no. At 37 miles per second, Perseids are the second fastest major meteors. Each typically lasts only a single second and acts as if it's playing a sort of game, trying to cross the sky when nobody's watching. When someone shouts, "Look at that!" it's already too late. So the key is to let the audio track play voices while the video screen displays nothing but starry sky. You get used to it after a while. By the next day you're routinely chatting with people while facing away from them, doing nothing to dispel the notion that astronomers are a bit eccentric.

Now the shower is underway. What happens when a particularly bright meteor splits the sky? Everyone gasps. It's predictable. But why do people do that? We rarely gasp in everyday life except when opening credit card bills. What is it about ugly little sky-stones that have this psychological power over humans? (Canines notice the moon but never howl at meteors, and cats couldn't care less.)

Maybe it's the surprise factor, although if you're out there waiting for the next shooting star it's hardly unforeseen. Whatever. The reaction is deep and involuntary and so well known that movie directors, who always try to create emotions, sometimes attempt to exploit "meteor power" by placing characters in front of a sky that includes a shooting star or two. But despite the sophistication of today's special effects, meteors in the movies don't cut it. They visually resemble real shooting stars, but deliver no visceral impact whatsoever. The same is true of synthetic planetarium meteors. Representative, but no juice. Whatever it is that makes us react, it has to be the real thing.

This gut-level impact has spawned countless historical myths about the "meaning" of shooting stars. Afghans, for example, believe that each meteor represents a demon being destroyed by an angel.

A few important Perseid facts and tips:

TIMING RHYME: Midnight to four and you'll see more. As to "where," it's best to fix your eyes about 40° above Perseus. After midnight, that means just about straight up.

MISFITS: Tracing back each meteor's path takes you toward Perseus's famous Double Cluster in the northeast. But a half dozen meteors an hour won't come from that direction. These are the strays, the sporadics, the meteors that, unlike Perseid members, do not originate from comet Swift-Tuttle. Sporadics are often brighter and have different colors or unusual speeds. They just don't *fit in*. This makes them strangely exciting, and worth recognizing.

DUCK? A slower-moving Perseid with a very short trail is a meteor coming straight toward you. It just happened to hit Earth's atmosphere heading in the direction of your blanket. After 1 A.M. you'll see not only more meteors but a higher percentage that seem to be trying to kill you. (Insurance note: Shower meteors are made of flimsier materials than the stones and metals of fallen meteorites. Not a single shower meteor has ever been known to survive its passage through the atmosphere.)

WHAT IT IS: The blazing streak is glowing air in front of and behind the incoming meteor, ionized from collisions with meteoric material. You don't usually see the meteor itself, unless those new contact lenses can let you spot a raisin in the next county, 60 miles away.

HOW FAR? Every meteor you see is somewhere between 50 and 120 miles away from you.

SAY AGAIN? Meteors are silent. Or are they? Occasional reports of accompanying crackles or hums that do not lag behind the meteor are no longer dismissed as delusions. Air ionization creates radio noise, and some people can apparently detect this electromagnetic radiation, possibly through the metallic fillings in their teeth.

Radio signals from Perseids beamed to your head? You never know. Watch them long enough and you might actually get a buzz from these summer meteors. Or maybe you're merely detecting that other August streaker, the one that covets your body fluids. Final checklist item: Mosquito repellent.

THE FUTURE: NASA's Peter Jenneskens, arguably the world's leading meteor expert (and the only one who accurately predicted the strong U.S. peak of last year's November Leonids) told me this spring that the Perseids will actually improve in the coming decades and centuries. Earth now only grazes the inner regions of this swarm, and its sunward, inward motion is carrying its meteoroids toward denser collisions with Earth in the years to come. With the Perseids, the best is still ahead. ■

Bob Berman regularly writes Astronomy's *"Strange Universe" column. He is also the author of entertaining and inspiring guides to the night sky, including* Cosmic Adventures.

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Hosted by the Cheyenne Astronomical Society and Laramie Astronomical Society and Space Observers, the 12th annual Weekend Under the Stars will take place August 8–10 near Foxpark, just 5 miles away from Laramie, Wyoming. This dark sky location is at 9,100 feet, making it the highest major star party in the country.

Scheduled events for the weekend include observing, a tentative tour or observing session at the University of Wyoming's Jelm Mountain Infrared Observatory, door prizes, a mirror grinding class, and swap table.

For more information, contact Marty Curran at (307) 635–5944; e-mail mcurran@sisna.com; website, http://users.sisna.com/mcurran.

Craig Stott

The dependable Perseids will highlight star parties held in mid-August.

JULY 31–AUGUST 3

ALCON 2002

University of Utah, Salt Lake City, Utah. Sponsored by *Astronomy*, the Astronomical League, and the Salt Lake City Astronomical Society. The ALCON 2002 mission is to provide a first-class astronomical convention that will allow knowledgeable amateur and professional astronomers to gather together, learn from each other and exchange ideas. For more information, contact Lowell Lyon, bolide@sisna.com; website, www.alcon2002.org.

AUGUST 2–6

Astroblast 2002

Oil Region Astronomical Observatory, Two Mile Run County Park, Franklin, Pennsylvania. The event will feature dark sky observing, both professional and amateur speakers, a swap meet, vendors, and much more. For more information, contact John O'Hara, (814) 677–3972; e-mail astroblast@oras.org; website, http://www.oras.org.

AUGUST 2–11

Summer Star Party

Shady Pines Family Campground, Savoy, Massachusetts. Spend one day or ten at the *11th annual* Summer Star Party – the choice is yours. Adult registration is $30.00 and includes free meals on weekends. SSP is family oriented and a great place to spend a summer vacation. Kids build and launch rockets on selected evenings. For more information, contact Don Urban, (201) 768–3295; e-mail, donurrban@rocklandastronomy.com; website, http://www.rocklandastronomy.com/entry-page.htm.

AUGUST 3

Cuyahoga Astronomical Association Annual Convention

CAA Observatory, Letha House Park, Chatham Township, Ohio. For more information, contact Bob Wiersma at (440) 779–5852; e-mail, RRW28141@aol.com; website http://www.geocities.com/cuyastro.

AUGUST 4–9

Nebraska Star Party

Merritt Reservoir, 27 miles south of Valentine, Nebraska. One of the premier attractions of the ninth annual NSP is the fantastic view of the summer Milky Way. Registration is $15 for adults and free for children 12 and under. For more information, call (402) 489–8197; e-mail, nsp@4w.com; website, www.nebraskastarparty.org.

AUGUST 8–11

Oregon Star Party

Indian Trail Spring, Ochoco National Forest, east of Prineville, Oregon. In its 15th year, the Oregon Star Party has steadily grown in popularity with over 800 people attending last year. Held under skies that are often steady, dark and transparent, the main emphasis is observing. Organizers will add other activities, including speakers, telescope training, youth activities, and even a Mars Rover race to round out your day. For more information, e-mail ospinfor@patch.com; website, http://www.oregonstarparty.org/.

AUGUST 9–11

Lava Star Party

Lava Hot Springs, Idaho. This event offers an excellent dark southern horizon and plenty of room for campers or RVs. For more information, contact Tom or Jeanine Lawler, (208) 776–9746; website, www.lavahotsprings.org.

AUGUST 9–10

Montana Starwatch

Harley Park, 45 minutes south of Great Falls, Montana. For more information, contact Mike Murray, (406) 994–7309; e-mail, mmurray@montana.edu; website, www.montana.edu/smasweb/swatch.html.

AUGUST 9–11

Northwoods Starfest

Hobb's Observatory near Fall Creek,

Wisconsin. For more information, contact Ray Forsgren, S1 County Highway K, Fall Creek, WI 54742; website, http://cvastro.org.

AUGUST 9–11

Nova East Star Party

Smiley's Provincial Park, Nova Scotia, Canada. Hosted by the Halifax Centre of the Royal Astronomical Society of Canada, the Minas Astronomy Group and the Nova Central Astronomy Club. For more information, contact Dave Parsons, (902) 835–9396; e-mail, novaeast@rasc.ca; website, http://halifax.rasc.ca/ne/home.html.

AUGUST 9–10

Stellafane

Breezy Hill, Springfield, Vermont. For more information, visit their website at www.stellafane.com.

AUGUST 12–24

CUREA Summer Program

Mount Wilson Observatory, near Pasadena, California. The Consortium for Undergraduate Research and Education in Astronomy (CUREA) will repeat its highly successful program at Mount Wilson Observatory for the 13th time. The program is aimed at undergraduate physics and astronomy majors with junior or senior standing who are considering a career in science or science teaching. For more information, contact Michael Faison, m-faison@northwestern.edu or Joe Snider, snider@ecology.coa.edu; website, www.curea.org.

AUGUST 12–18

Great Manitou Star Party

Gordon's Park & Carter Bay on Manitoulin Island, Ontario, Canada. The cost to attend is $20 per vehicle per night. Experience the joy of stargazing in a magnificent, natural setting. For more information, contact Mark Oldfield, (705) 897–4518; e-mail greatmanitou@hotmail.com; website; www.manitoulinlink.com/starparty.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our online calendar at http://www.astronomy.com.

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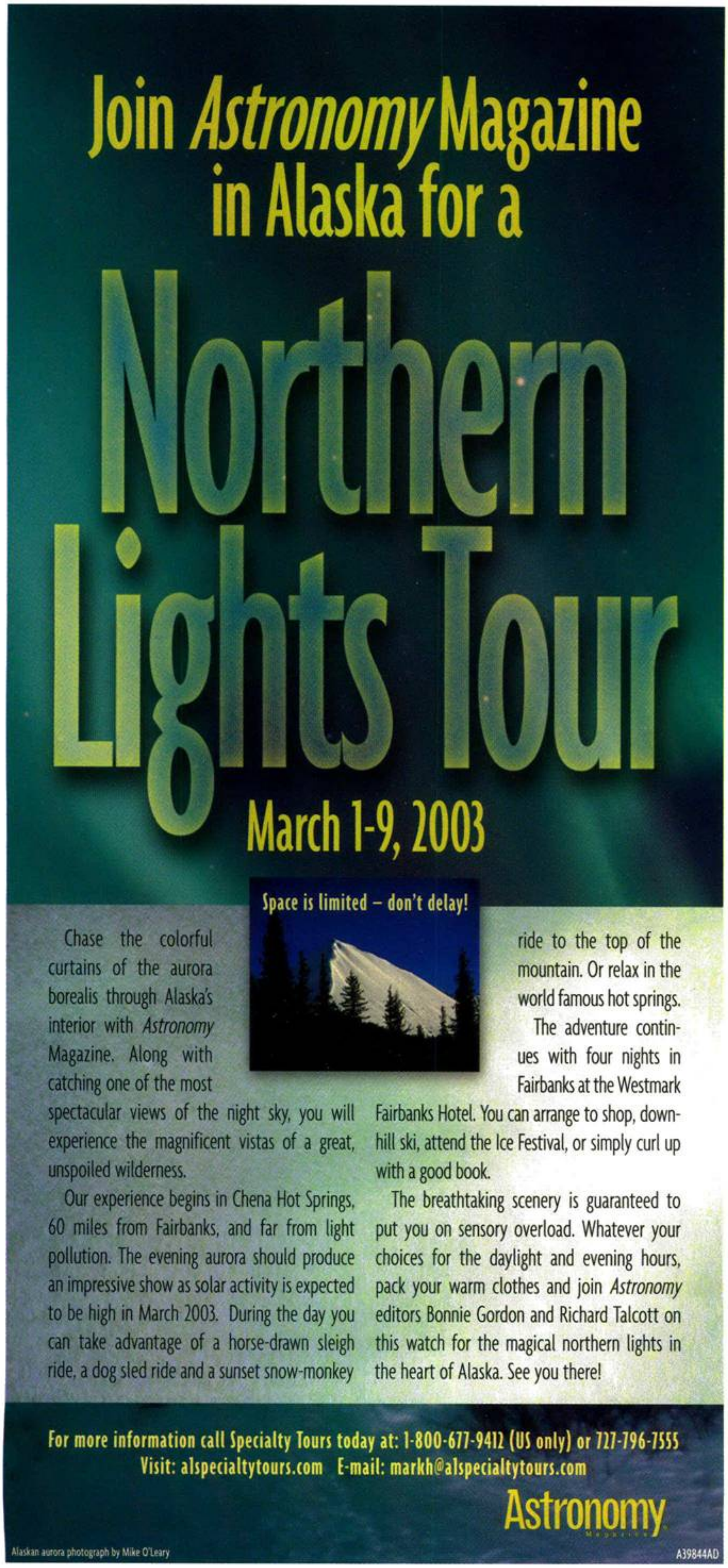

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March 1-9, 2003

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Chase the colorful curtains of the aurora borealis through Alaska's interior with *Astronomy* Magazine. Along with catching one of the most spectacular views of the night sky, you will experience the magnificent vistas of a great, unspoiled wilderness.

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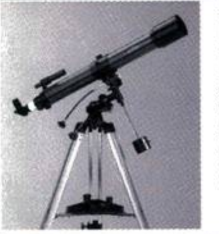

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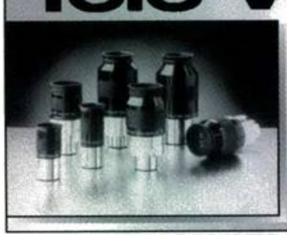

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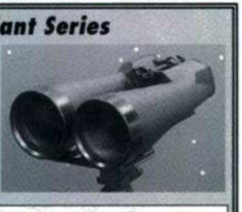

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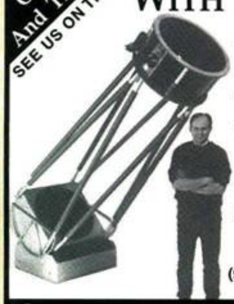

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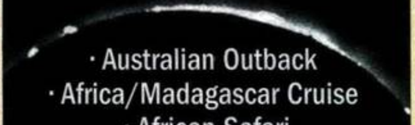

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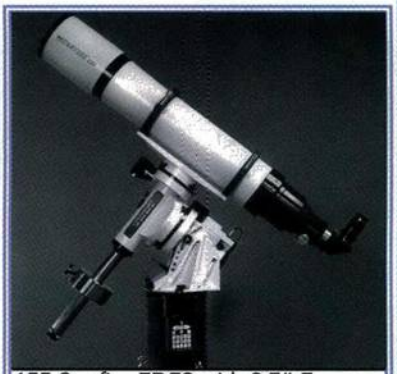

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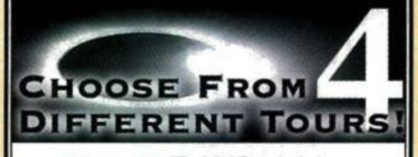
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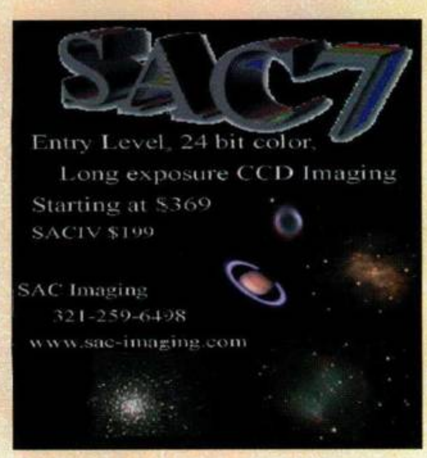

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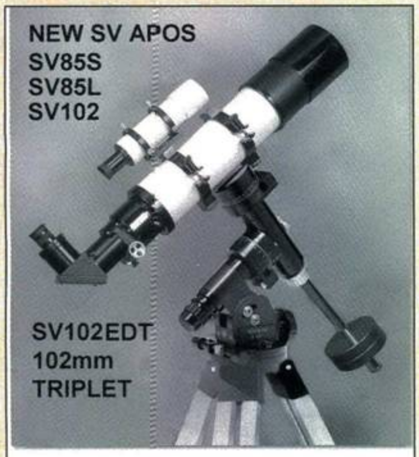

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*Patent Pending

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We now stock over 50 kits to fit all popular Digital Cameras, Call or visit our website for details!

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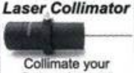

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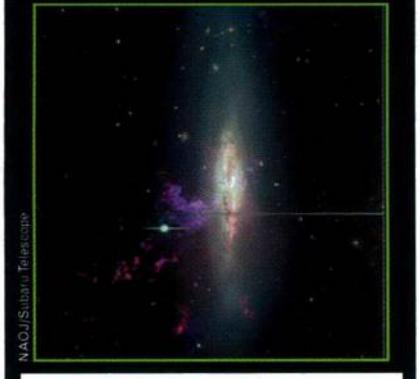
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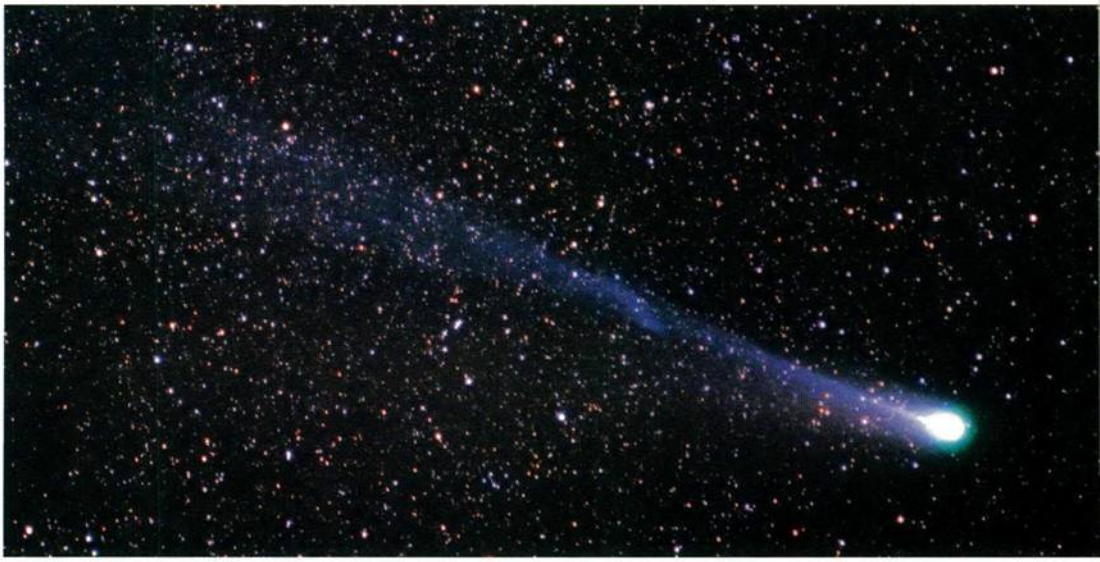
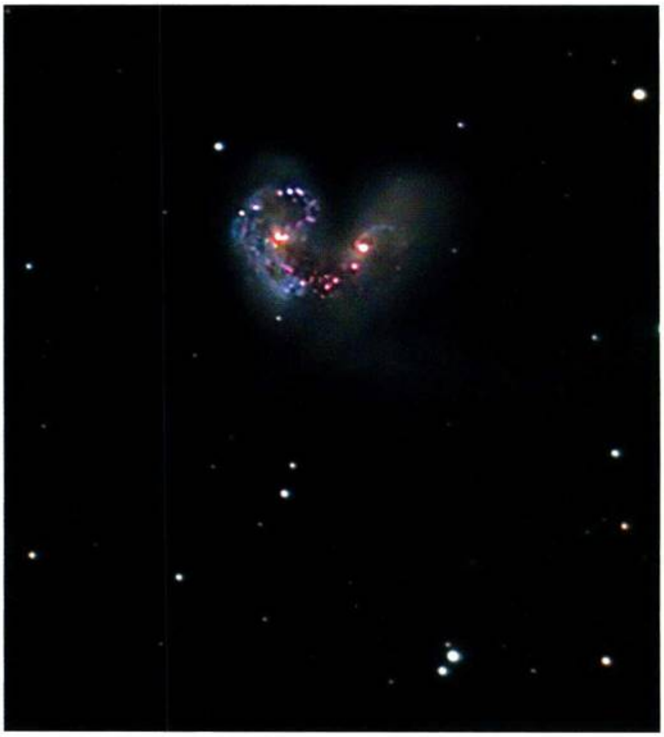
February 26, 1998. The day was hot and sunny, perfect for a solar eclipse. We were in the town (actually more of a village) of Santa Rita, which is on the eastern shore of Lake Maracaibo in Venezuela. My family and I were posted in the country for a few years, living in the capital city of Caracas. Our plant was in Santa Rita, which also happened to be directly in the path of the last solar eclipse in the Western Hemisphere in the twentieth century. It was the perfect opportunity to catch an unforgettable astronomical event, and I couldn't wait.

Before the day of the eclipse, I hosted three discussions with our company employees, in the best Spanish I could muster, about why and what we were about to see. The people were genuinely interested and surprisingly informed. The city of Maracaibo had been doing a tremendous job of telling the residents (population of about one million) about the eclipse, and how to safely view it. Many people had small Mylar coated pieces of plastic and seemed prepared to make a party out of the event. You don't need much of an excuse to have a party here; in fact, several companies (but not mine, of course) gave their employees the afternoon off; even the government of Maracaibo decided to take a holiday to view the event.

On the morning of the big day, an interesting article appeared in the newspaper





Top: Comet Ikeya-Zhang

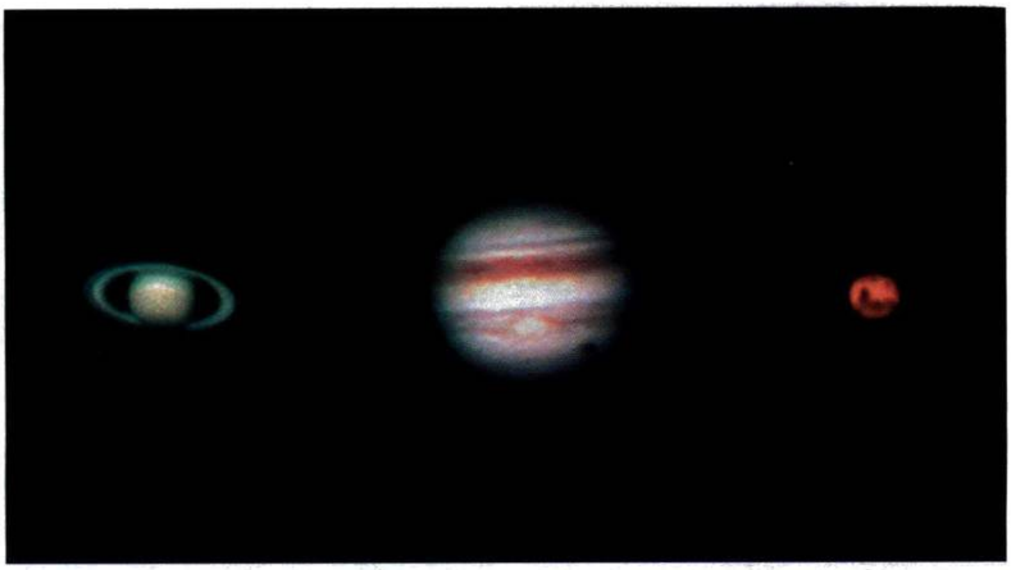
ANTHONY GALVAN III

(300mm lens at f/2.8, Fuji 800 film, 5-minute exposure taken April 14, 2002)

Bottom: NGC 4038 and NGC 4039 (the Antennae)

RICHARD JACOBS

(9.25-inch SCT at f/10, SBIG ST-8e CCD camera, composite exposure taken April 13, 2002)



Saturn, Jupiter, and Mars

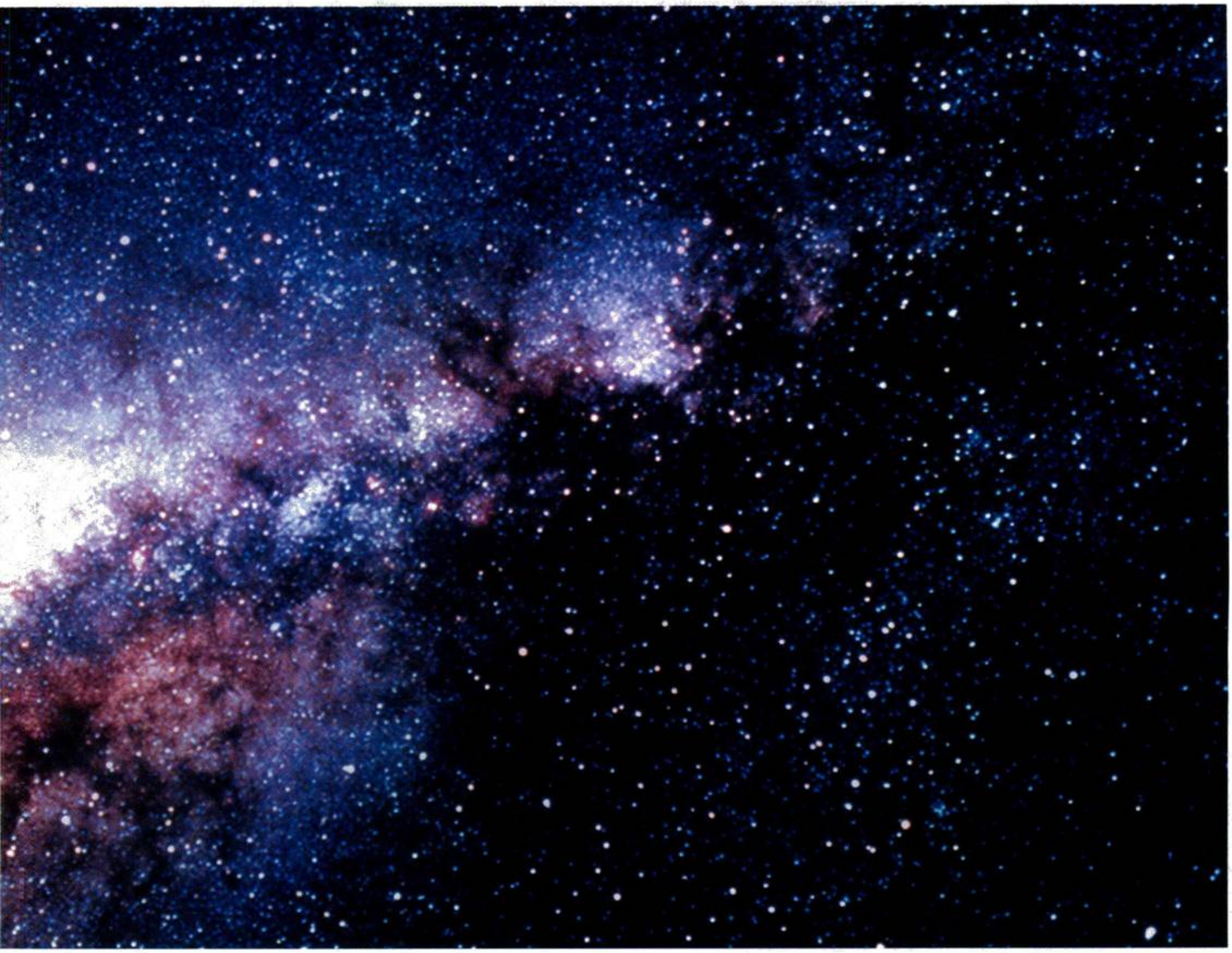
JOHN CHUMACK

(Jupiter and Saturn: 10-inch SCT at f/10, ST-9 CCD camera; Mars: 10-inch SCT at f/6.3, Astrovid video camera; composite image)

Milky Way, from Serpens to Sagittarius

JOHN CHUMACK

(80mm lens, 30-minute exposure taken July 4, 1997)



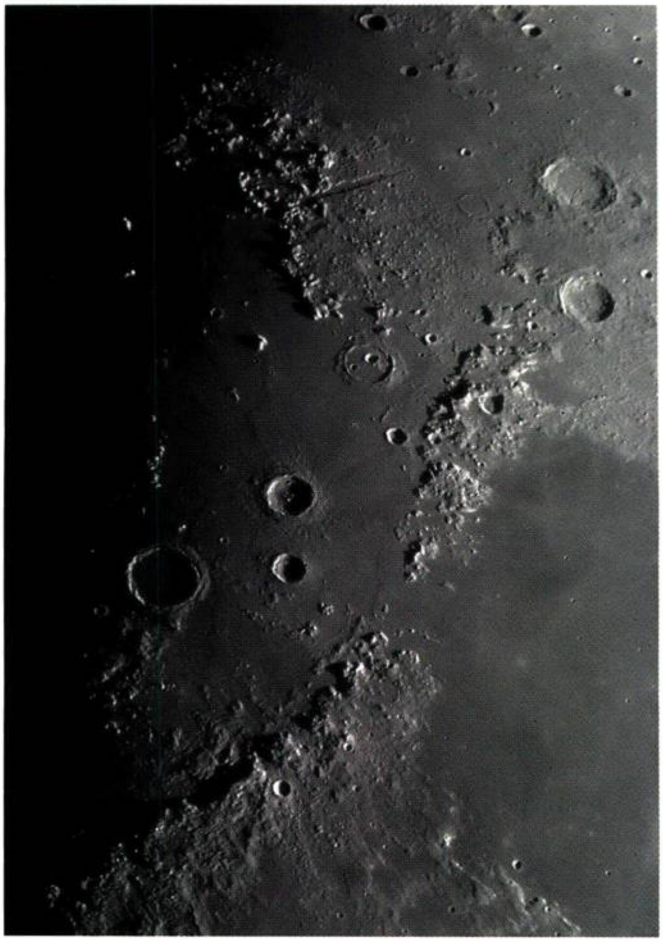
about one of the many indigenous people of Venezuela, the Wayuu, who live in the desert peninsula straddling Venezuela and Colombia in the northwestern part of Venezuela. They refused to look at the eclipse because they believed that the sun and the moon were joining to produce new stars, which should be kept private between the two of them. But we decided to watch anyway.

I set up my telescope, a 4-inch Meade SCT complete with a Mylar solar filter, around 10 A.M. to give it time to adjust to the temperature. Instead, it immediately fogged up from being in air conditioning all night. However, by noon it was fine, ready for first contact at 12:31 local time. We taped on a thermometer to measure the temperature change. Before the eclipse began, it read a balmy 38° C (100° F).

Everyone was anxious to look through a telescope for the first time, especially to view the sun. As the moon began to take larger and larger bites from the sun, I could feel the excitement build. With about 10 minutes until totality, it was becoming noticeably cooler and darker quickly.

Suddenly, someone spotted Venus off to the west of the sun, and the excitement level went up a notch. By now we had a group of about 30 people gathered to share this remarkable natural phenomenon. With only minutes left, it became difficult for all of us, including me, to resist the urge to look at the sun with unprotected eyes.

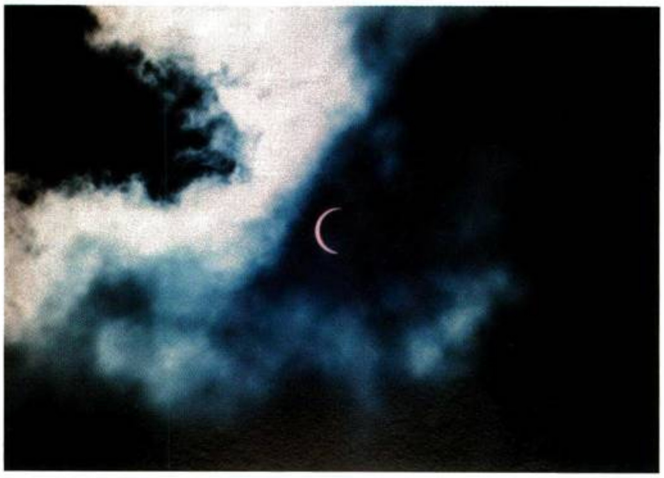
Finally, the diamond ring appeared, a brilliant spotlight on the edge of the moon, providing legitimacy for the union the Wayuu refused to look at. Suddenly it was dark, as if the sun had set 30 or 40



Surface of the Moon

H.J.P. ARNOLD

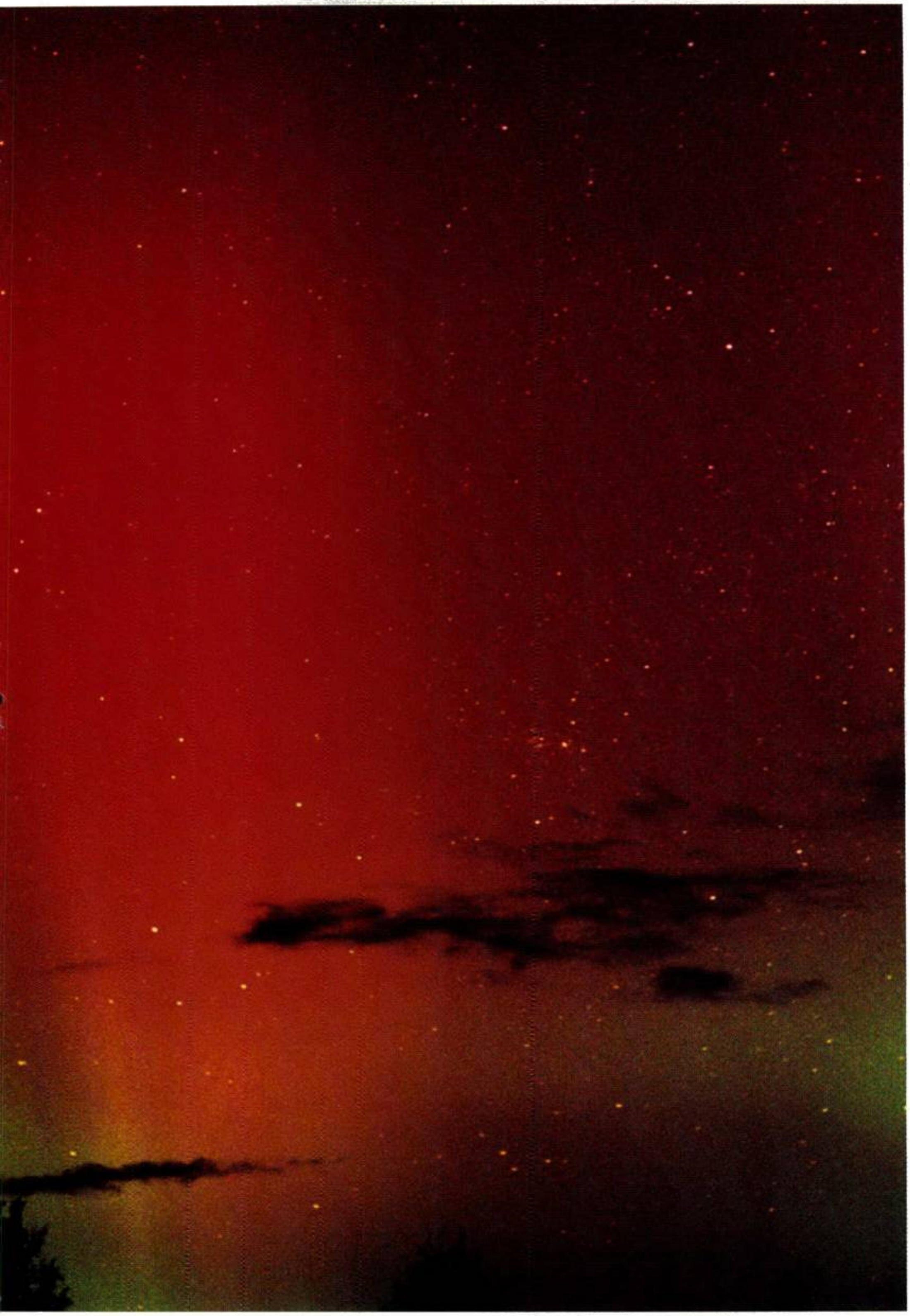
(178mm refractor, Nikon D1 digital camera, taken in a 4-meter dome)



1984 Solar Eclipse

JOHN P. MCKENZIE

(250mm lens, Kodak 200 film, taken from Grayson County, Virginia, in the Blue Ridge Mountains)



Bright Aurora

LYNN CARROLL

(50mm lens at f/2, 12-second exposure taken April 17, 2002)

minutes earlier. Experiencing this unusual change felt eerie but exhilarating at the same time. The automatic streetlights in the plant turned on, while the birds that fly to the area every morning from the other side of the lake rose together to go back home for the "night." Jupiter and Mercury were guarding the magnificent corona. We snapped a few pictures by hand of this rare sight. But in the midst of the excitement, I forgot to take off the solar filter and examine the corona through the telescope.

In what seemed to be only seconds, the diamond ring appeared on the other side, signaling the end of totality. Although it was entirely too short, the experience proved to be just as amazing as I had hoped it would be.

After the excitement died down, we looked at the thermometer to find that the temperature was now 31° C, (88° F) a full 7° C (12.5° F) cooler than before. Instead of hot and balmy, it was now quite comfortable. At that moment the birds returned, although not quite as orderly as they had left.

Looking at all the smiling, excited faces, I knew we had shared a once-in-a-lifetime experience that day, one that we would remember forever.

Tom Murphy works as a foreign correspondent and enjoys observing from his hometown in Chattanooga, Tennessee.

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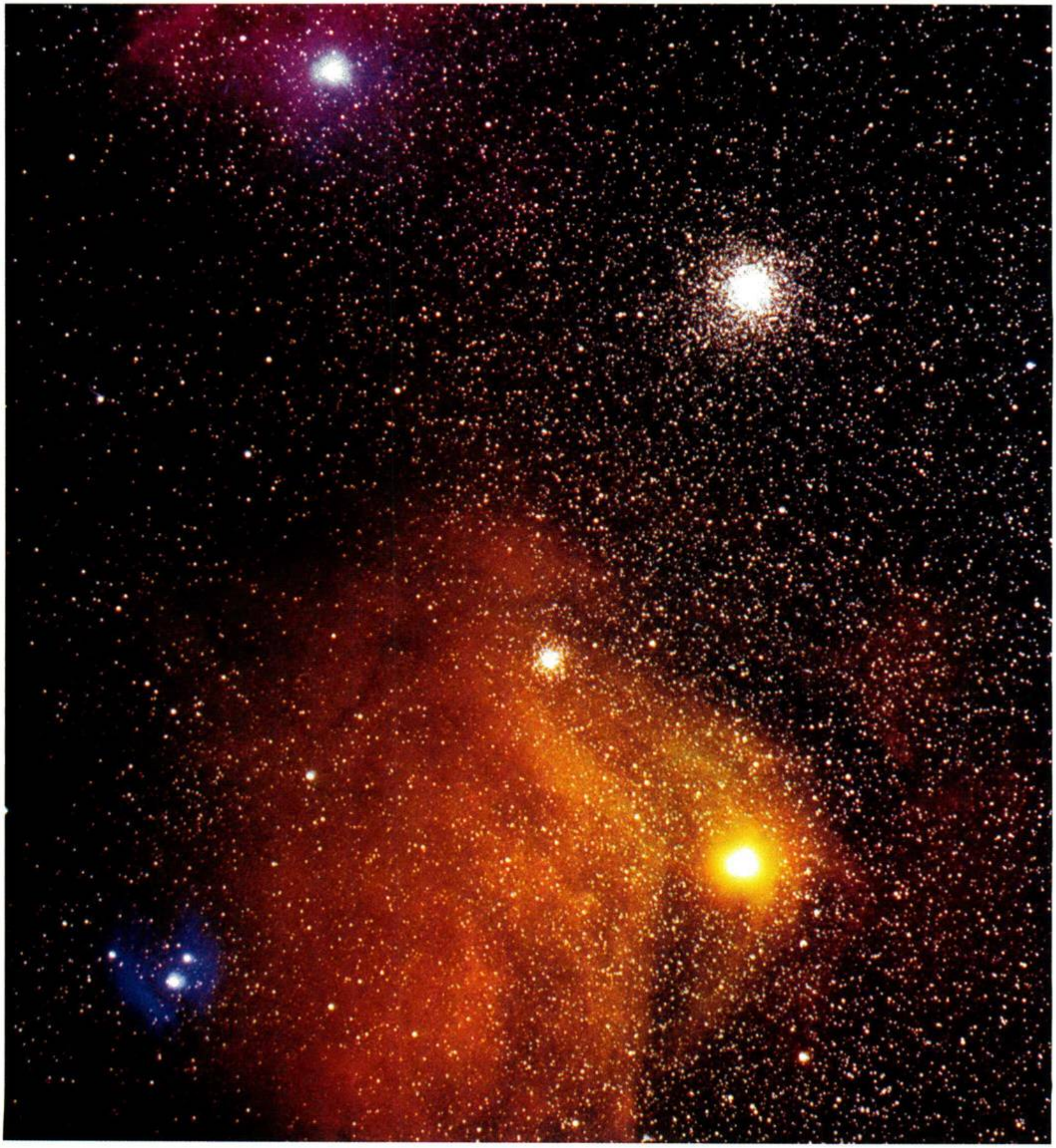
This month's best astrophoto



IC 4606

GEORGE GREANEY

(6-inch refractor at f/7, hypered Kodak 400 film, composite of three 45-minute exposures)

This colorful reflection nebula surrounds the bright star Antares.

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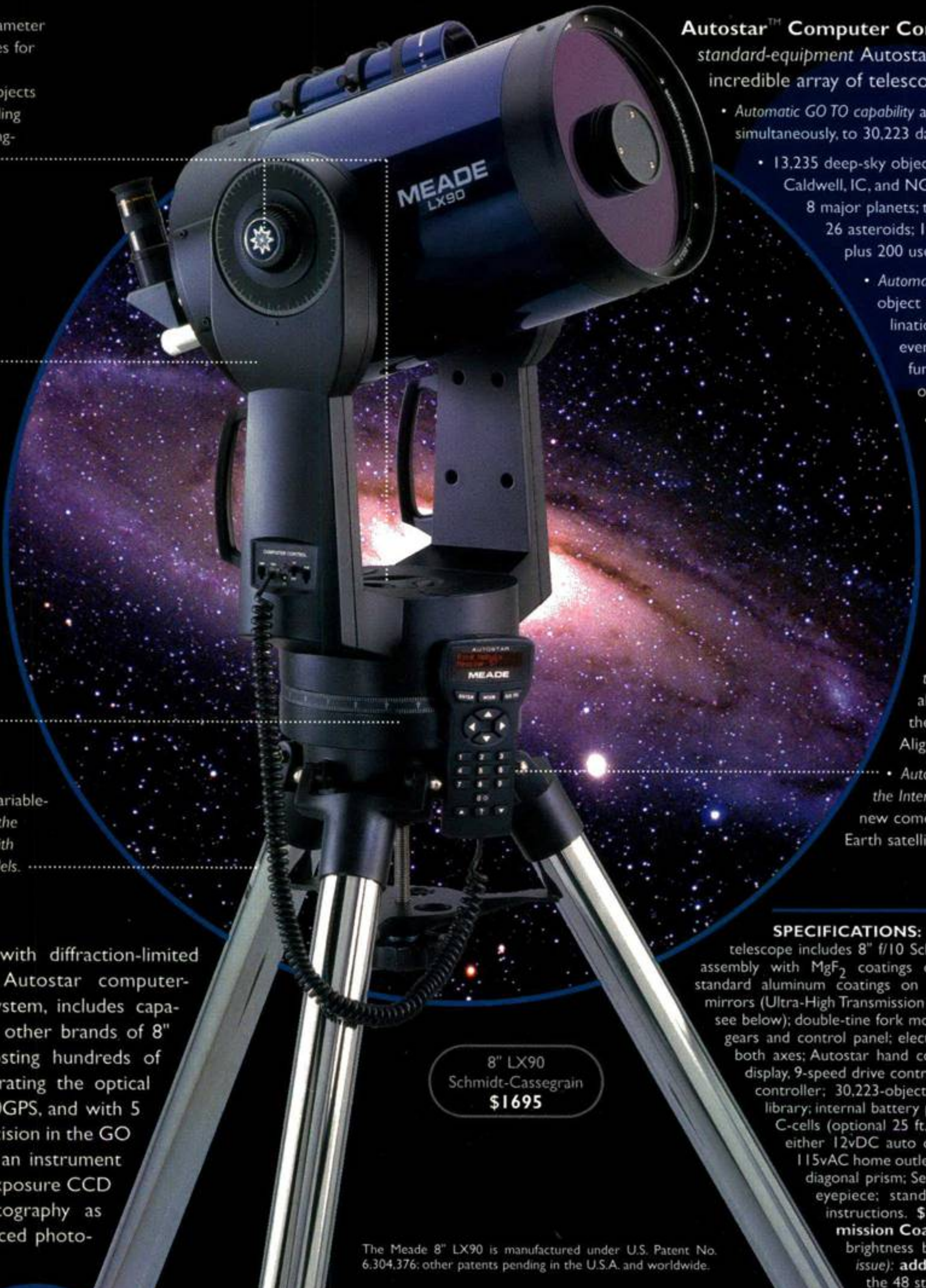

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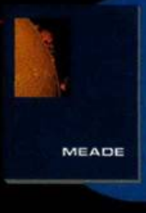

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